# COMBUSTION

MAY 1 1932

Vol. 3, No. 11 MAY, 1932 25c a copy

Vienna Plant, Eastern Shore Public Service Company

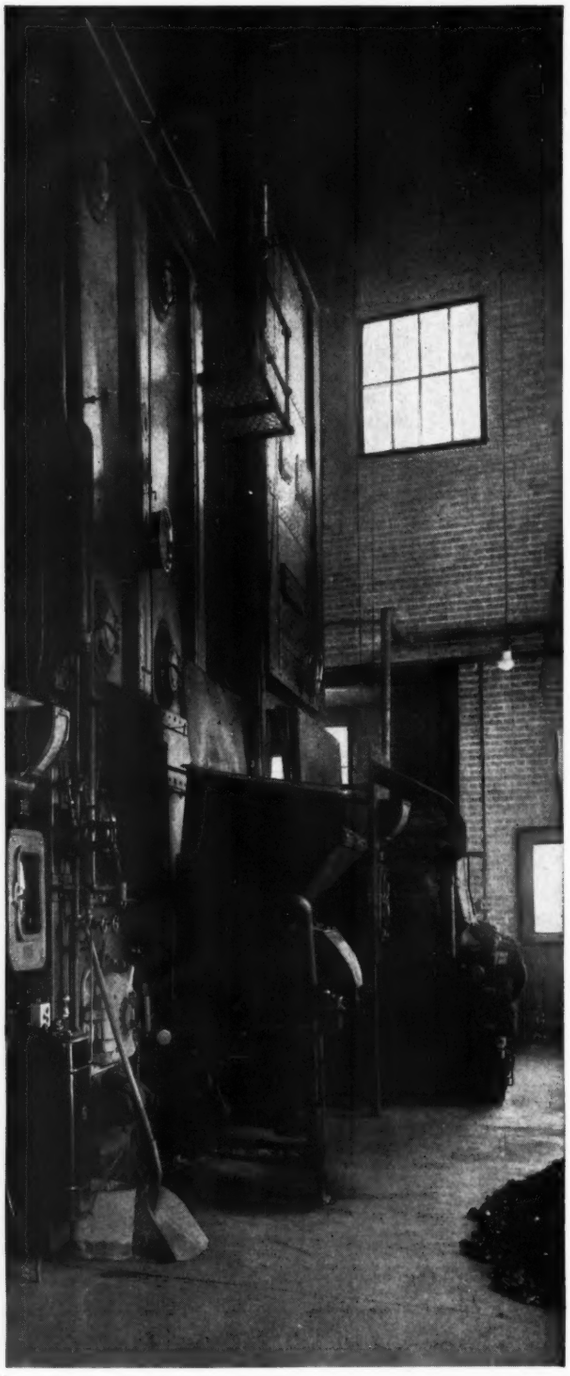
**Electrical Methods Proposed for Preventing Scale and Corrosion in Steam Boilers**
By WM. L. DeBAUFRE

**Water-Cooled Furnaces for Underfeed Stokers**
By OTTO de LORENZI

OTHER ARTICLES IN THIS ISSUE BY
A. J. MOSES • GEORGE RAMSEY • F. H. ROSENCRANTS • DAVID BROWNLIE

# THIS STOKER

## PAID FOR ITSELF IN ONE YEAR



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# COMBUSTION

VOLUME THREE • NUMBER ELEVEN

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COMBUSTION is published monthly by In-Ce-Co Publishing Corporation, a subsidiary of International Combustion Engineering Corporation, 200 Madison Avenue, New York. London office, Aldwych House, Aldwych, W.C.2. W. R. Wood, President; George H. Hansel, Secretary; W. I. Branigan, Treasurer.

SUBSCRIPTIONS, including postage, United States and Great Britain, $2.00 a Year. Canada $3.00 (includes Canadian tax). Other countries, $3.00. Single copies: 25 cents.

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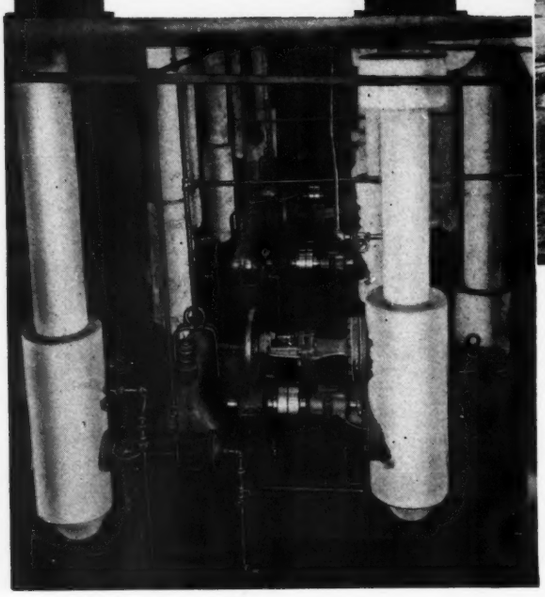
# 14 Turbines at Bush Terminal



*Left: Typical battery of three Westinghouse Type 2-AMD Turbines driving Worthington boiler feed pumps in Bush Terminal.*

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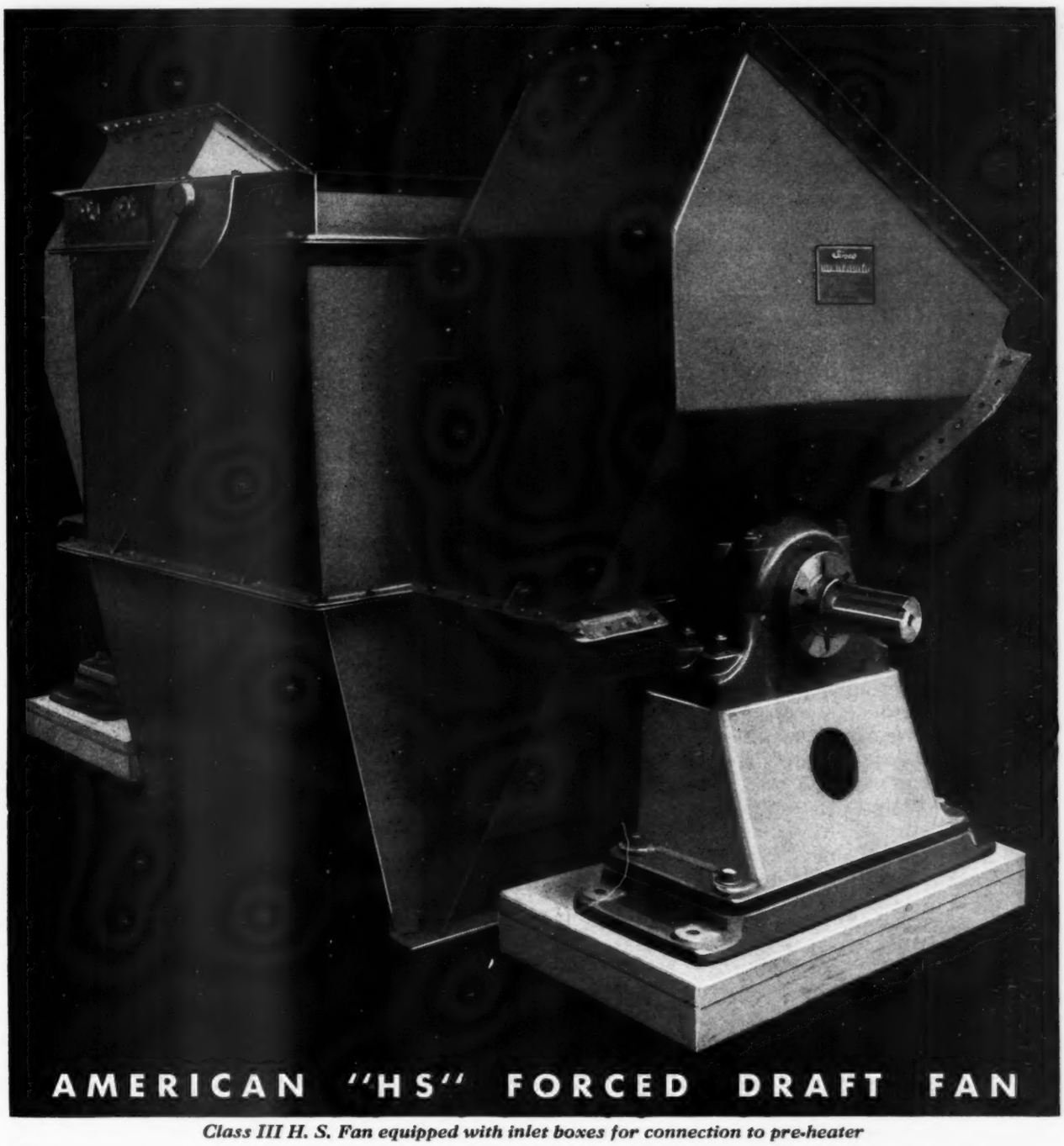


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# EDITORIAL

## Pressures, Temperatures and Cycles

THE number of power stations now operating on the high-pressure reheat cycle is such that, over the next few years, sufficient data should become available to indicate the overall advantages or disadvantages of this cycle as compared with more moderate pressures without reheat. That there is an advantage of several per cent in heat rate per kw-hr. is already established. Other factors, such as reliability, availability, flexibility in operation, maintenance, etc., which, taken as a whole, measure the commercial utility of a method or practice, are, however, not yet established to the general satisfaction of the industry. The final answer will not be available in the form of a written report, bearing authoritative approval, but will be reflected in decisions governing the design of new installations by engineers whose judgment commands respect.

Recent development in the use of high temperature is certain to exert an important influence; such influence is in fact already apparent. In some few cases, those active in the advancement of the reheat cycle state that they now foresee the high-pressure reheat cycle of moderate temperature as a transitory stage which may ultimately give way to the straight-through cycle using a pressure of 500 to 700 lb. with a temperature of 900 to 1000 deg. fahr. without reheat.

The use of still higher pressure with extremely high temperature hardly seems probable,—first, because the added increment of gain due to the added increment of pressure which may be realized in practice is not large, and, second, because the cost of construction and the difficulties to be overcome in design and operation, when combining high pressure and high temperature, are economic obstacles that cannot be readily surmounted.

The present trend is somewhat obscured by the absence of any considerable volume of new work up for immediate consideration. Such limited work as is now being actively considered, however, would seem to indicate a trend to the simple cycle without reheat with a pressure of 500 to 700 lb. and a steam temperature of 825 to 875 deg. fahr.

However pessimistic the view which may be taken of the future of the high-pressure reheat cycle, the industry is greatly indebted to present plants for distinct advancements in the art which are contributing to the building of better plants whether they be of the super high-pressure reheat cycle or the moderate-pressure, high-temperature variety. For example, the science of feedwater treatment has been tremendously advanced; the design and construction of boiler feed pumps has been greatly improved; gage glasses for high pressure have been perfected; forged steel drums and electric welded drums have been commercially developed; piping standards, flanged joints, and fittings have been greatly improved; and specialties in general have undergone intensive development and improvement all as direct requirements of super high-pressure operation. The importance of these developments when applied to plants yet to be built whether of the super-pressure, reheat-cycle type or of the moderate-pressure, high-temperature type will be conceded by all.

The use of high pressure together with the urge for higher and higher temperature has stimulated intense activity in the acquirement of further knowledge concerning the behavior of materials commonly available and in the development of new materials. Future improvement in steam plant performance promises to be primarily a reflection of more accurate knowledge concerning present materials and the development of materials better adapted to high temperature conditions.

## Modern Research Technique

AN interesting example of modern research technique is given in this issue in the article, "Electrical Methods Proposed for Preventing Scale and Corrosion in Steam Boilers." Here the problem was to determine the effectiveness of certain systems of this type.

First a list of practically all the patents in this field was secured and the more important of these selected for study. This study revealed the theories and principles upon which these patents were based as well as the actual methods developed for accomplishing the patent claims. With this background the investigators turned their attention to the several systems to be evaluated and proceeded to check their performance by laboratory tests, experiments and actual field investigations.

This was not intended to be an exhaustive investigation of the subject. The primary purpose was to determine the practical value of certain selected methods. Nevertheless, the investigators saw fit to review the history of the art and to acquaint themselves thoroughly with the principles involved before attempting to reach conclusions.

Such investigations obviously do not always produce results that have commercial value to the sponsor commensurate with the cost. On the other hand when the results have immediate commercial value, the industries served generally benefit in larger measure than the sponsor both in direct economies obtained through the use of improved methods and in the many advantages that ultimately attend the direction of development along the lines of correct principles and economic practice.

# History and Developments in the Art of Welding Ferrous Metals

## PART IV

By A. J. MOSES
Hedges-Walsh-Weidner Company
Chattanooga, Tenn.

**The fourth and concluding article in this series is devoted to the development of welding for pressure vessel applications. As is generally known, this development has come to the fore very rapidly during the past two years. Although the A.S.M.E. Code covering welded construction of power boilers was issued less than a year ago, the welding of boiler drums has already become an established practice and appears destined to become the principal method of fabrication in this field. . . . Mr. Moses gives a practical and intimate turn to his discussion of this phase of the welding development by telling of the experiences and practice of his own organization which has pioneered in this branch of the welding art.**

NOTHING heretofore has so stimulated interest in the welding art as its proposed application to boilers and pressure vessels. It has furnished the greatest incentive to improve this art. The admittedly rigid requirements so necessary in such welding application has brought about a codification of reliable testing methods. Previous to this awakened interest in the art little was known concerning the possibilities of welding. Most of the welding processes were held in sufficiently bad repute as to prohibit their use in the manufacture of boilers. The belated decision that this method of joining plates could be made applicable to such construction brought about a thorough investigation of welding. The dependable and standardized test methods newly instituted have thoroughly discredited even that welding which has heretofore been considered good. Besides rooting out many false ideas, the accurate information derived from such testing has led the way in obtaining confidence in a reconstructed art. In a large measure the interest aroused by pressure vessel welding has been directly responsible for the remarkable progress made in the art during the past decade.

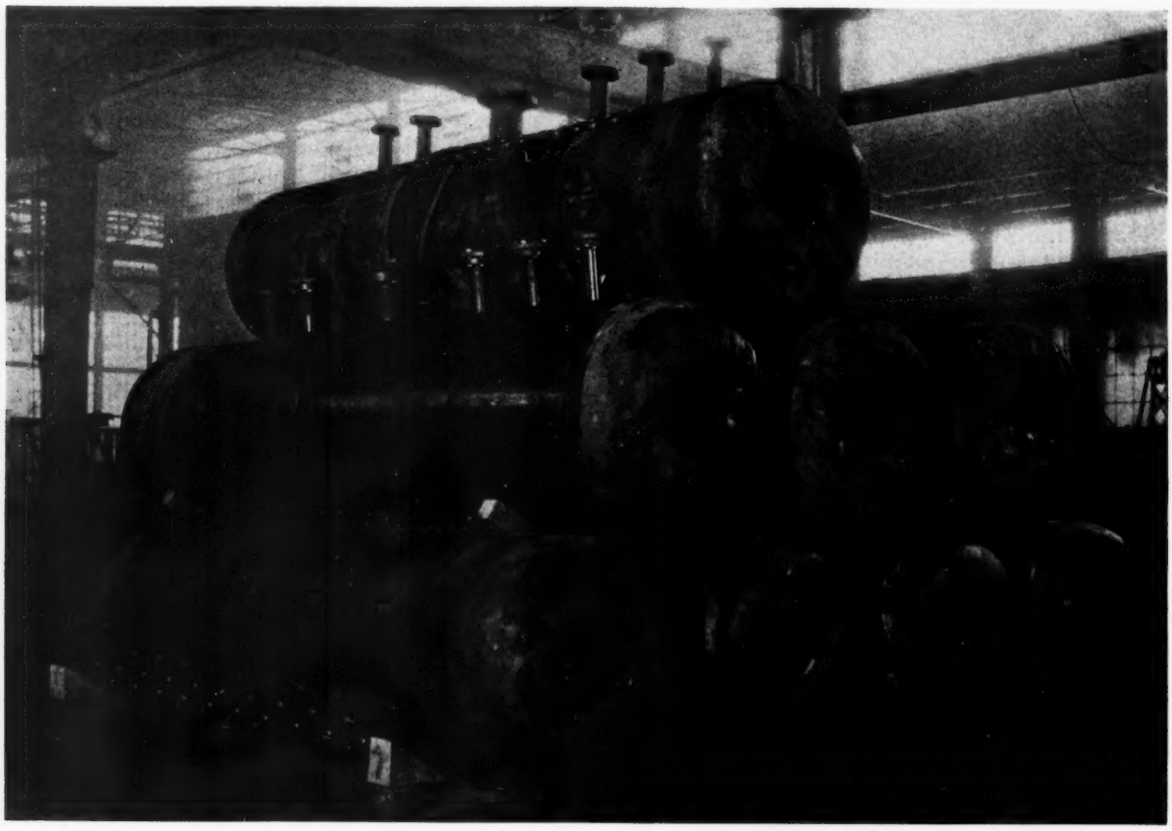
The advantages to be derived from welding in this industry have long been appreciated. In fact it had been used to a small extent for many years. Experience gained from this and its use in effecting repairs did not increase confidence in the art. In connection with low pressure vessels of light plate thicknesses, it was considered unsafe construction. Its employment in the growing heavy plate fabrication was apparently out of the question. However it was the advent of high pressure vessels that made welding a live issue. The general weaknesses of riveted construction were emphasized in the building of heavy wall vessels. Manufacturers began to realize that the possibilities of improving welding were better than those of riveting. Also the realization that ideal welding was much to be preferred over ideal riveting gave added impetus to the movement.

Long experience in the manufacture of riveted pressure vessels had proven that a ductile, low carbon steel is necessary in such construction. The ability to withstand shocks and fatigue stresses makes this material much more suitable than the higher tensile strength steels. Also from a practical fabricating standpoint such material is easier worked and shaped. It is less apt to be injured by improper working and heating. The A.S.M.E. Boiler Code specifications for boiler plate prescribes this type of steel as being the most desirable for this purpose. Fortunately this was one of the most weldable materials. The problem of ideal welding lies in the securing of a joint or weld metal of the same physical and chemical properties as the base material. It was realized at once that stress relieving or heat treatment of entire vessels would be necessary. All welding methods from their very nature result in highly stressed areas and in metallographic structures inferior to the plate material. The excellent physical properties of the latter are principally due to the refining operations through which it passes as a unit during its manufacture. Welding undergoes no such refining processes. Welding being essentially a localized operation, joints and adjacent plate material are subject to the ill effects of unequal heating and sudden chilling. If intrinsically good, welded joints can be vastly improved by subsequent annealing. There-

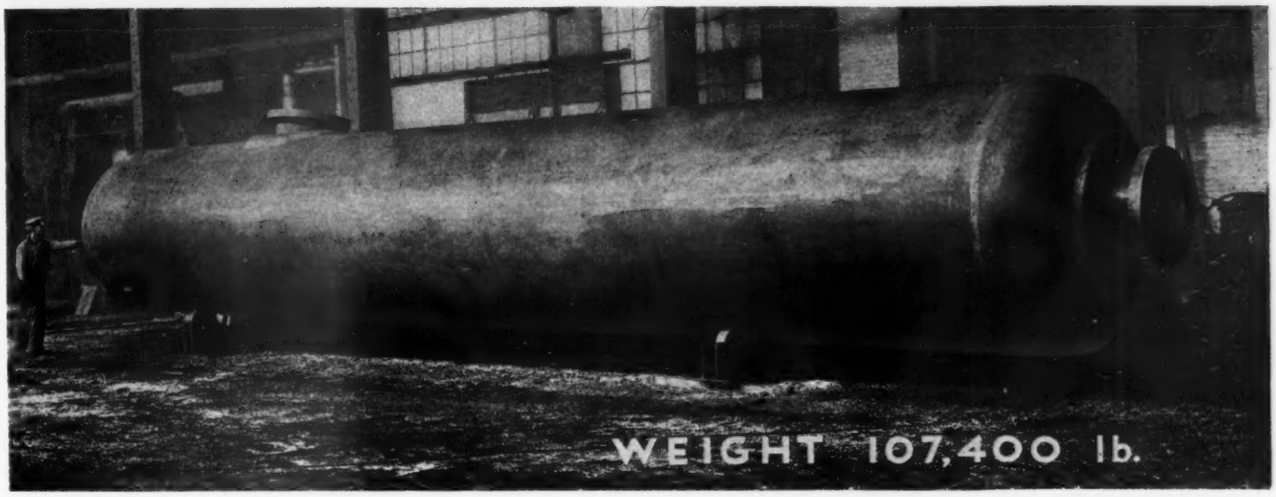
fore the problem is reduced to the requirement of a consolidated, sound joint of clean metal, chemically, like the plate.

In so important an application of welding the need of rigid test requirements is evident. Proper testing has played a leading role in the development and maintenance of safe construction. In this field it is extremely important. In riveted construction it could not be slighted. The strength of the poorest riveted joint will vary little from that calculated. But calculations must rely on the accurate testing of materials. The design and workmanship and the quality of the materials used must be continually checked. In connection with boiler plate material it is admitted that the most rigid testing is superfluous. The time of running a heat of open hearth steel is a matter of hours. The metal is dealt with in a large unit. The procedure is long established. Time is afforded for continuous checking and treatment if necessary. Being a large mass, a fair degree of uniformity in treatment and results is assured. Long experience has taught how to identify and correct harmful conditions. With welding the reverse is true. While the operation may be continuous, the actual joining of unit areas is almost instantaneous. Little time is afforded for the detection and correction of errors. Welding is a sensitive operation. It is susceptible to slight changes in many contributing factors. The quality of the joint is largely dependent upon the constant control of these factors. The chances against uniformity are large. Variations in quality can and do occur within the same joint. Welding has not the metallurgical background of the Siemans-Martin process of making steel. Causes and effects are not yet thoroughly understood. Therefore the entry of welding into the pressure vessel field calls for the most rigid testing. The accuracy of the calculated strength and service expected of a weld joint depends not upon what has been or can be done, but rather upon test result closely related to the particular joint.

Interest in such welding requirements has been general. A few years back the interest of several companies took a practical turn. These companies undertook a serious study and development of the welding art in relation to the known requirement for pressure vessel application. While the formulation of a code was a joint effort, the selection and improvement of welding procedures were undertaken separately. One of these firms was The Hedges-Walsh-Weidner Company, a subsidiary of International Combustion Engineering Corporation. The writer has been in charge of the welding research done by this company since the inception of the work, and, in order to give the reader an appreciation of the problems that had to be met, both in the selection of a welding method and in its development to meet the exacting requirement of pressure vessel application, he will discuss the experi-



**Group of eight welded boiler drums ready for shipment. These drums vary in length from 13 ft. to 18 ft. 2 in., are 42 in. in dia. with shell thickness varying from 1 7/32 in. to 1 5/16 in. They are to be used in two 612 hp. boilers designed for 450 lb. pressure.**



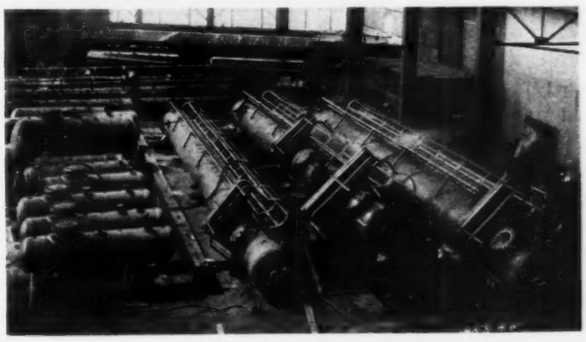

**Welded boiler drum 46 ft. long, 78 in. dia., 2½ in. shell thickness.**

ence and present practice of his own organization.

At the time this work was begun it was felt that no preliminary study was necessary to establish the evident unreliability of the common welding methods. The company had gained considerable experience in dealing with acetylene and with both manual and automatic arc welding. These methods had been used with some degree of satisfaction in structural work and in the fabrication of tanks and range boilers. But their use was not permissible in important seams of power boilers and pressure tanks. In particular cases they were used in the manufacture of the latter vessels where the stresses were supposedly carried by staybolts or rivets. Even this limited use was the source of some trouble and expense. The defectiveness of such welding made evident the need of improvement.

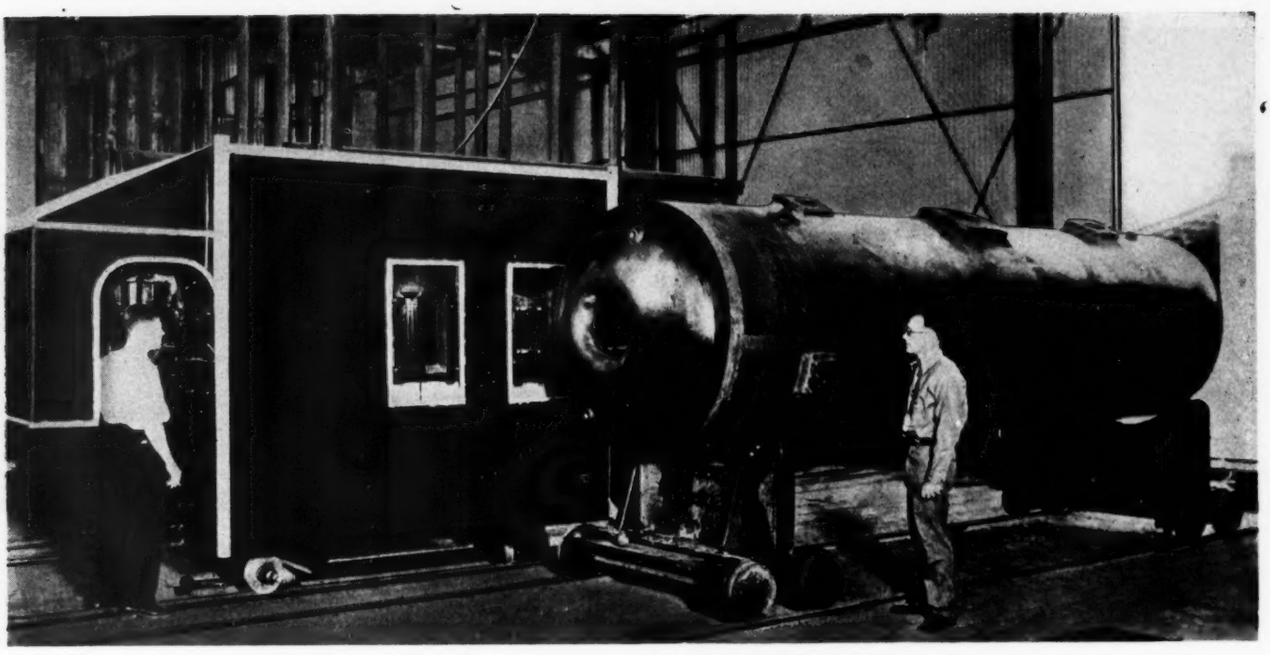
The selection of a method best suited to this class of work required a more detailed study. There were many factors to be considered in making such a selection, that of quality requirements being uppermost. That the process must be practically and economically applicable was self-evident. Fortunately the material to be welded offered no great difficulties in itself. But the sizes, shapes and thicknesses encountered in pressure vessels eliminated quite a few of the welding methods on the basis of quality and practical and economical applicability. While resistance welding ranked high in regard to quality, it was not considered economically adaptable. No usable process was sufficiently trustworthy for this work. None, in which the human element was a negligible factor, was available. The nature and seriousness of probable defects in connection with the various methods was important. The ability to detect and repair such defects without recourse to several welding methods was considered most desirable. Strangely enough, that process which had given some of the poorest results, metallic arc welding, was chosen. The extreme simplicity and flexibility of this method had commended it to many investigators. Coated electrodes for metallic arc welding had been introduced some years before. Many brands of these had been used by The Hedges-Walsh-Weidner Company. While they had not attained their present state of development, sufficient improvement had been obtained to justify the expectation that metallic arc welding could be made satisfactory for pressure vessel welding.

Stress relieving was accepted as a necessity. Opinion concerning this has not changed. The desirability of an efficient non-destructive test was appreciated. At that time this aid was thought unobtainable, or rather it was thought that the proposed methods were impractical. Since that time, x-ray examination of weld joints has proven both practical and efficient. (This valuable test method should receive the unqualified endorsement of all manufacturers and users of welded pressure vessels.) No standards had been established for the testing of weld joints. Published test data were unintelligible. This is still true to a large extent.



**Fifteen welded pressure vessels ready for shipment to a vapor recovery plant in a South American oil refinery.**

There seems to be an aversion to reporting tests in terms of established codes. For instance, the tensile strength of weld metals is often published together with photographs of specimens showing a reinforcement of unknown amount at the joint. Also the heat history of the samples is neglected. The tensile strength is often calculated for weld metal through which a series of holes has been



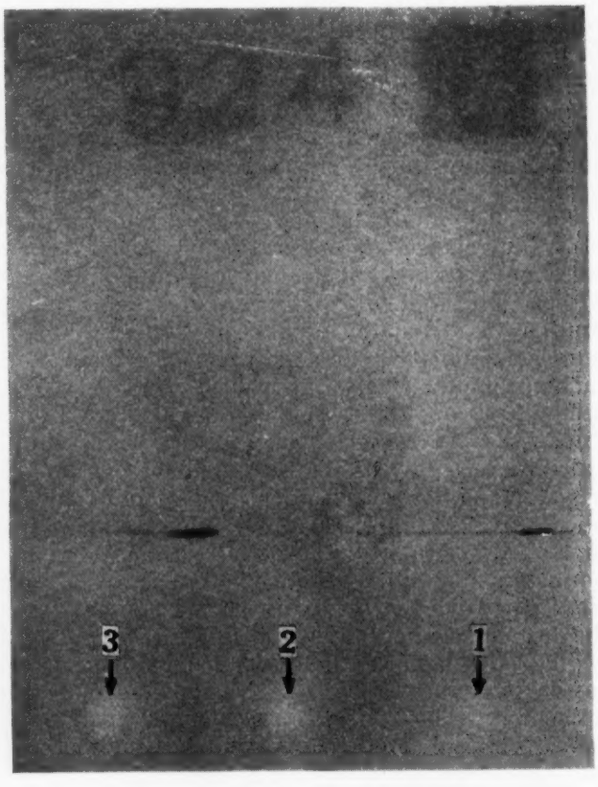
**Exterior view of x-ray car with welded drum in position for radiography.**

drilled. This gives fictitious results. In some cases elongation has been given in terms of the elongation of these holes. Photographs of bend samples have been shown wherein little perceptible bending has occurred in the weld joint. Much of this is unimportant but nevertheless misleading. We have all been guilty of having striven to present these matters in a novel and spectacular manner. It was necessary to combat just such a condition of affairs in formulating a reliable test code. From the start of this development The Hedges-Walsh-Weidner Company realized the importance of correcting these conditions and has been willing to cooperate in the standardization and codification of test methods.

The welding procedure finally developed was the result of an extended study of the many variables encountered in metallic arc welding and involved an immense amount of experimental work. It may be described as a mode of fusion welding which embraces the use of a shielded metallic arc, the employment of selected materials and welding equipment, and the establishment of an efficient procedure and a trained organization. Since the adoption of the A.S.M.E. Welding Code all welded vessels have been checked and tested in compliance with the provisions of that Code. This has been under the supervision of an inspection agency which has followed closely the development of this application.

The development work, as well as the routine checking of production jobs, necessitated the installation of a fully equipped laboratory. Numerous tests have been made of various electrodes and base materials. The effects of the size of electrode and current characteristics have been studied. Means of controlling the arc, arc lengths and the requirements of welding machines have been investigated. A satisfactory and unique covering material for the weld rods was early attained.

From a careful investigation of good and bad results the proper technique was established. As was expected, chemical and physical testing was

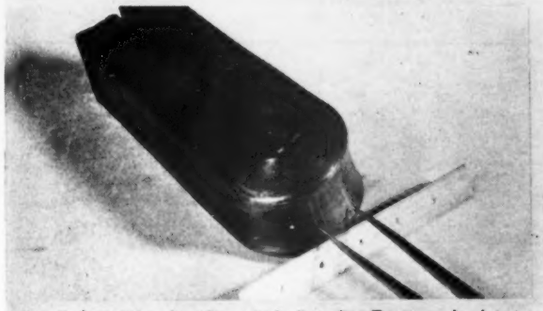



**Radiograph of weld seam in 4 in. thick boiler plate**

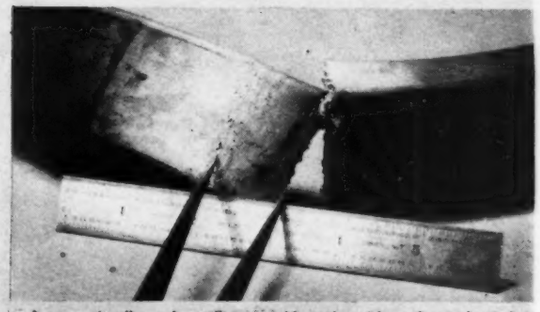
Weld reinforcement removed—centerline of seam extends horizontally through center of photograph. Numbered light spots show holes drilled in plate material to following depths: No. 1—.16 in., No. 2—.24 in., No. 3—.32 in. (The drilled holes as well as the marker and number at the top of the plate showed up clearly in the original photograph which also showed an additional hole drilled to a depth of .08 in.)

Fusion weld. Metallic arc weld made with a coated electrode. Transverse bend test of stress relieved specimen. Plate thickness is 2 in. Elongation of outer fibers of deposited metal amounts to 98 per cent. Note elongation of Brinell mark.

Metallic arc weld made with a coated electrode. Transverse tension test of a stress relieved specimen. Plate thickness is 1 in. Note that a long reduced section results in plate failure to side of weld where no serious defects are present in the welded joint.

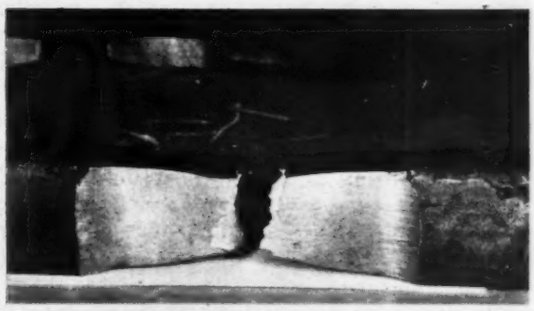


Metallic arc weld made with a coated electrode. Transverse bend test specimen. Plate thickness is 1 in. Specimen has been stress relieved. Elongation of outer fibers of deposited metal amounts to 60 per cent.

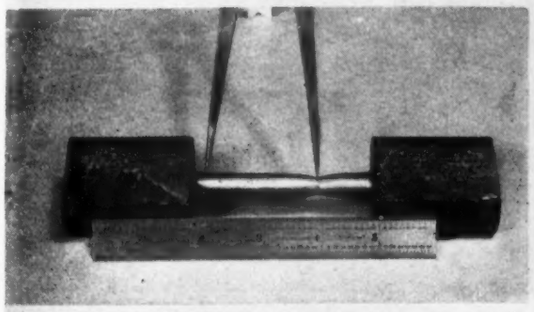


An exceptionally good metallic arc weld made with a bare electrode. Transverse bend test specimen. Plate thickness is 1 in. Specimen has been stress relieved. Elongation of outer fibres of deposited metal amounts to 22 per cent.

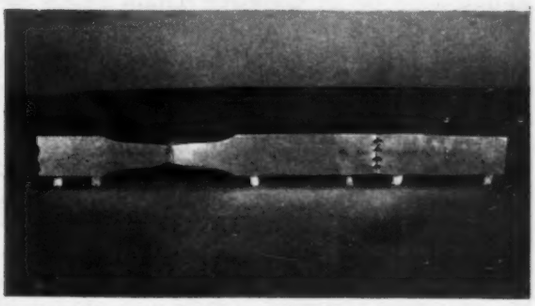
Metallic arc weld made with a coated electrode. Stainless steel of the 15 per cent to 18 per cent chrome variety. Transverse bend test of an annealed specimen. Plate thickness is ½ in. Elongation of outer fibres of deposited metal amounts to 30 per cent.



Metallic arc weld made with coated electrode. Transverse tension test specimen. Plate thickness is 2 in. Specimen has been stress relieved. Tensile strength—59,850 lb. per sq. in. Failure occurred through center of deposited metal. Note the ductility of this metal as shown by the reduction in area at this point.

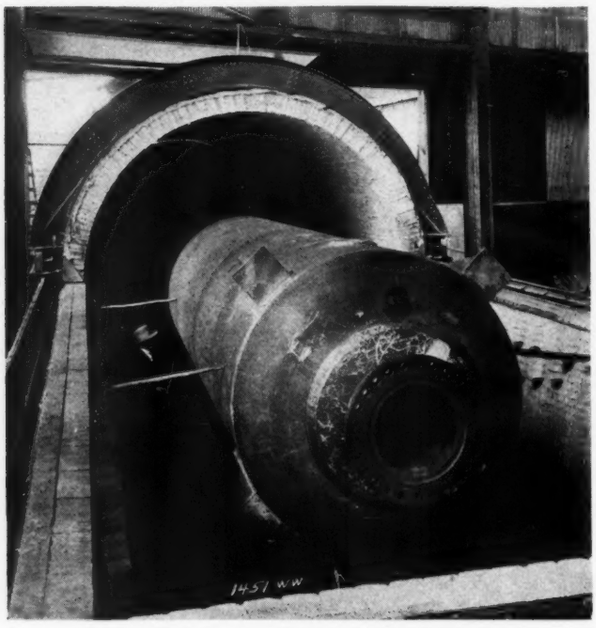


Metallic arc weld made with a coated electrode. Test specimen of all weld metal. Diameter of coupon is ½ in. Yield point—40,000 lb. per sq. in. Tensile strength—63,250 lb. per sq. in. Elongation in 2 in.—32.5 per cent. Specimen has been stress relieved.



Tension specimen made of boiler plate material. Net area at both points of failure was 1 sq. in. Tensile strength at machined section was 59,600 lb. Tensile strength at drilled section was 76,300 lb.

found necessary in the control of electrode and plate material. Difficulties were encountered making indispensable the checking and controlling of practically all of the elements entering into the welding operation. Since the operator, whether



**Welded drums shown within annealing furnace.**

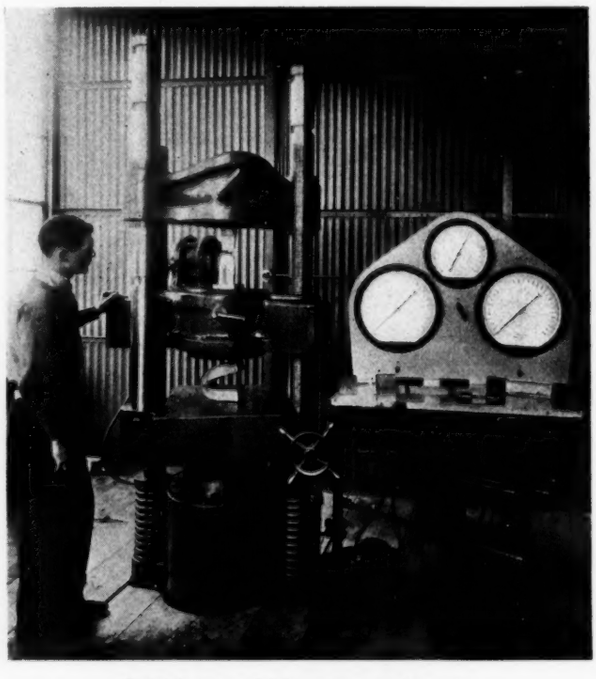
manual or machine, is the most uncontrollable agent present, an attempt was made to minimize the effect of human errors. This has been rewarded with a fair degree of success. If no errors are committed by those responsible for the preparation and carrying out of the welding procedure, almost infallibly good results will follow. No organization can measure up to this degree of efficiency. While conscientious inspection and reliable testing will divulge the seriousness of defects, their correction is generally expensive.

For this reason, and not through any lack of faith in testing methods, it was desirable to give all welders a thorough training course. After a preliminary training in the rudiments of the art, they were given plates one inch thick and thirty inches long to be welded. These plates were of sufficient length to insure the use of more than one electrode in the laying of each bead. Each welder, without assistance, was required to produce at least five consecutive welds without flaws. These samples were subjected to all the tests prescribed by the A.S.M.E. Code for Grade I welding. Joints giving practically perfect radiographs were demanded. Physical test results considerably above the Code specifications were also required. After successfully completing this training course, the welder was adjudged qualified to weld on plate thicknesses up to one inch. Before being permitted to weld on heavier material, he was required to make additional samples of 1½ in., 2 in., 2½ in,. 3 in. and 4 in. plate. All such weld samples have been clamped rigidly so as to prevent warping and to insure the locking up of all shrinkage stresses.

In addition to the above, attached samples have been required for every production job, regardless of the grade of welding specified. Each welder has been assigned a number. A complete test record for each welder is maintained. This includes both qualifying and identifiable production welds. All samples have been stress relieved in accordance with Code requirements, but have not been normalized. The results of nearly 500 samples of qualifying welds is given below. These were made by various welders, most of whom were novices in the welding art. The lists include both the acceptable and the unacceptable welds. That is, they constitute a complete history of the qualifying tests of the welders from their very first efforts:

| Test | Code Requirements | Average Results | Per Cent Failures |
|---|---|---|---|
| Free bend test..... | 30 per cent elongation outer fibres | 50.7 per cent | 2.6 |
| Transverse tension... | 55,000 lb. per sq. in. | 58,300 lb. per sq. in. | 9.1 |
| Specific gravity, all weld metal..... | 7.80 | 7.842 | 1.2 |
| Yield point, all weld metal ..... | 27,500 lb. per sq. in. | 38,800 lb. per sq. in. | 0 |
| Elongation in 2 in., all weld metal..... | 20 per cent | 29.45 per cent | 5 |
| Tensile strength, all weld metal..... | 55,000 lb. per sq. in. | 60,000 lb. per sq. in. | 5 |

Practically all of the samples which failed physically were radiographically unacceptable. The fact that the transverse tension test shows more failures is worthy of note. These samples were not machined according to Code specifications to force failure in the weld metal. The reduced section was



**Partial view of laboratory equipment.**

machined somewhat wider than the weld so as to disclose possible side-wall defects. Radiographs show that inexperienced welders have more diffi-

culty here than elsewhere. Tensile specimens having such defects will not always fail in physical requirements if the reduced section is not considerably wider than the welding groove. Also the location of specific gravity samples as specified in the Code does not totally include side-wall defects. In many cases the specific gravity came up to requirements, where radiographically the joint was undesirable.

In production work these same records are maintained. This constitutes a perpetual qualification test of welders. This company has produced many unfired pressure vessels and boilers before and since the adoption of the present Code. All such welds were, of course, made by qualified welders. A compilation of the test records of these to within a short time ago gave the following results:

| Test | Average Results | Per Cent Failures |
|---|---|---|
| Free bend test..... | 51 per cent elongation of outer fibres | 0 |
| Transverse Tension ..... | 59,500 lb. per sq. in. | 0 |
| Specific gravity, all weld metal.. | 7.845 | 0 |
| Yield point, all weld metal..... | 41,300 lb. per sq. in. | 0 |
| Elongation in 2 in., all weld metal | 31.75 per cent | 0 |
| Tensile strength, all weld metal.. | 61,200 lb. per sq. in. | 0 |

Physically the most noticeable superiority of this welding over that of unqualified welders is in consistency. There is very little difference in average physical results. The difference is most clearly shown by radiography. X-ray examination, as applied to this particular welding process, has proven a more rigid inspection tool than the physical testing of attached samples. The maximum porosity allowed has been much less than is acceptable under the new Code. No complete welds have been rejected on the basis of radiography, but many local defects have been discovered and removed. The superiority of x-ray examination over other tests is not maintained in every case. Since the compilation of the above data, two entire welds have been rejected and re-welded on the basis of physical properties. While the radiographs of these were good and the test results above Code requirements, the quality was so far below previous standards as to cause removal and replacement of this metal. From this experience, the complete testing of welded vessels, as prescribed, is deemed necessary in the production of joints of unquestionable quality.

**Welded pressure vessels ready for shipment. These vessels are all designed for 250 lb. pressure. The largest of the three shown is a bubble tower 59 ft. 8 in. long, 84 in. dia. and 1¼ in shell thickness.**

There are a number of welding processes now in vogue in the fabricating of welded pressure vessels. Each is probably susceptible to certain distinct weaknesses. A test code should furnish the means of detecting all such weaknesses. Manufacturers should willingly submit their product to these tests, even though some of them may appear unnecessary in some cases. With an increase in collective experience, some may be eliminated. On the other hand it may be necessary to add others. From the experience gained in the code testing of welds made by the above described process, the following conclusions have been drawn:

It does not appear probable that doubtful welds could result where unfired pressure vessels and boilers are built in accordance with the Grade 1 welding specifications of the new A.S.M.E. Code. These requirements are considered to be far from too rigid. The preparation of the transverse tensile test specimen could be bettered. The preparation of this sample as now prescribed, in an attempt to force failure within the deposited metal, leads to fictitiously high results. It may also fail to show the true value of the juncture between deposited metal and base material. A reduced section two inches longer than the width of welding groove would lead to more accurate results. The specific gravity test does not appear necessary since joints are x-rayed. The inspection of joints by x-ray

examination is held of the highest importance. Welds of a quality equal to that of the plate material cannot be produced under ordinary visual inspection.

This company has never been in sympathy with the leniency of the requirements for Class 2 welding as written in the new A.S.M.E. Welding Code. This refers both to the class of vessels in which this grade of welding is permitted and to the reduced test requirements as finally adopted. Experience gained in the production and testing of welds under Class 1 specifications has confirmed this position. While recognizing that the use of this grade of welding, is permissible in certain cases where plate thicknesses do not exceed 1 in., its use in pressure vessels which are to contain explosive gases or liquids is considered improper. Also, the substitution of periodical qualification of welders for test samples from each individual vessel will undoubtedly lead to an inferior grade of welding. No continuous checking of welding procedures is comparable to continuous checking of welding results. No one can deny the necessity of good welding in the fabrication of vessels which are to contain highly expansive fluids at elevated pressures and temperatures. No one can assume that good welds have been produced in the absence of reliable test data. The hydrostatic test is important, but not sufficient. More vessels have failed after succesfully withstanding this test than have failed during this test. Stress relieving is also important, but should be viewed as supplementary. It cannot make safe an unsound, unclean and structurally defective joint. At the present time x-ray examination of weld seams and physical testing of closely related samples are the most reliable means of determining the quality of welded joints.

By adhering closely to the Class 1 requirements of the Code, assurance can be given concerning the reliability of every vessel so constructed. The development of a correct welding procedure made such construction possible. The application of correct testing methods made such construction a fact. The maintenance of a higher standard entails a greater expense. This is to be expected and should be accepted in applying welding to this very important field of pressure vessel fabrication. The unknown concerning the welding art is still greater than the known. Most methods can and doubtless will be greatly improved. After lagging for years the accomplishments in steel manufacture, the welding art may possibly share the lead in the production of quality materials. Also better methods of testing may be devised. But the elimination of the necessity of rigid test requirements can hardly be anticipated.

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**Goulds Pumps, Inc.,** announces the removal of its Chicago office to 35 East Wacker Drive. The warehouse is at 217 No. Jefferson Street.

## E. B. Freeman Elected President of the B. F. Sturtevant Company

AT a meeting of the board of directors held on March 30, E. B. Freeman, formerly vice president and general manager of B. F. Sturtevant Company, Hyde Park, Mass., was elected president.

Mr. Freeman succeeds former Governor Eugene N. Foss, who becomes chairman of the board. He was educated in mechanical engineering at the Worcester Polytechnic Institute and has been connected with the Sturtevant company practically since his graduation. Starting in the sales engineering department, he served as manager of the power apparatus department, before becoming general manager.

Mr. Freeman is a member of the Engineers Club of Boston, the University Club, Brae Burn Golf Club. He lives at Bald Hill, Newton, Mass.

## Walter C. Baylies is Now President Boston Edison Company

The Edison Electric Illuminating Company of Boston elected Walter C. Baylies president succeeding the late Charles L. Edgar, at a special meeting held on April 18 for the purpose of completing the organization. In addition to the action taken on the presidency, Frank D. Comerford, president of the New England Power Association, was elected to the board and made a member of the executive committee.

For the past 33 years Mr. Baylies was chairman of the executive committee of the board of directors and long senior vice-president. He was graduated from Harvard College in 1883. His first association with the Edison Company was in 1891 when he became vice-president and director. His many directorships and banking, railroading and manufacturing connections have made him an outstanding figure in Boston business circles.

After the meeting the company issued a statement pointing out that the continuance of the policies of the late president is assured by the election of Messrs. Baylies and Comerford. Through close association with Mr. Edgar and his long vice-presidency and directorship, Mr. Baylies has been intimately acquainted with the company's policies and activities and familiar with its personnel. Mr. Baylies has been a director of the New England Power Association practically since its organization. The election of Mr. Comerford as a director of the Edison Company will, it is believed, assure the continuation of the cordial relations between the two companies and the Edison board will have the advantage of Mr. Comerford's intimate knowledge of the industry.

# Water-Cooled Furnaces for Underfeed Stokers

By OTTO de LORENZI
Combustion Engineering Corporation
New York

**In the earlier stages of its development, watercooling of furnace walls was considered principally in connection with pulverized fuel firing. As the development proceeded the possibilities of its application to stoker-fired furnaces were realized and many successful installations were made. This field of the water-cooled furnace has been more or less neglected in the technical press, and, consequently, COMBUSTION is glad to have the opportunity of publishing this able and comprehensive discussion of the subject. In a later article the author will deal with the application of watercooling to traveling grate stoker settings.**

AN appreciable item, in the cost of steam production, is furnace maintenance and the resultant boiler outage. This becomes even more apparent as the capacities of stoker-fired furnaces are increased. Improvements in stoker as well as furnace designs are such that it is possible to operate with a very low margin of excess air. Because of this fact the $CO_2$ content of the furnace gases is high and, as a result, the furnace temperature is also high. These conditions impose severe punishment on refractory linings, thereby accelerating their ultimate failure and requiring frequent renewal.

While the water-cooled furnace was developed for and found its principal use in pulverized-fuel-fired installations, it is also being applied, with considerable success, to many stoker-fired boilers. The application of these water-cooled linings has served to minimize furnace outage and to reduce maintenance to a point where these factors become quite insignificant in the total cost of steam production. In addition to reducing furnace maintenance, watercooling also serves to decrease the cost of stoker repairs. When a multiple retort type of stoker is installed in the conventional refractory furnace, the lower end of the machine is exposed to the excessive heat radiated from the incandescent bridge wall. If the coal burned contains a low percentage of ash, the protective coating of refuse at the rear end is very thin and as a result the grate surface will be burned in a short time. Using fuel of higher ash content may serve to reduce the action of the heat somewhat, by providing a thicker covering over the end of the grate. This covering, however, is lost whenever the ashes are removed and then the bare grate is temporarily exposed to the full furnace temperature. Because of the higher ash content of the fuel, it becomes necessary to clean fires often and before long we have the end of the grate burned and in need of repairs. Frequently the coal will contain an ash which has a relatively low fusion temperature. As a result bridge-wall clinkers will be formed and their size will usually increase with increased combustion rate. If not removed in time, they may extend from the bridge wall sufficiently to force a reduction in rating or even cause a shutting-down of the unit until their removal is effected. The application of watercooling to the bridge wall, when using either the dump grate or clinker grinder type of machine, will serve to reduce materially the amount of heat radiated to the rear end of he stoker. As a result, the temperature of the grate surface, even though exposed, is kept sufficiently low so that burning occurs at a materially decreased rate, or is entirely eliminated. Thus replacements are required only at infrequent intervals. In addition to cooling the grate, the water-cooled type of wall serves to chill the ash and refuse down to a point where the danger of clinker formation is eliminated. Furthermore the nature of the water-cooled surface, itself, is such that it would be practically impossible for clinker formations to adhere tenaciously to it.

Another source of annoyance, maintenance and reduction in operating efficiency is the formation of side-wall clinkers. These clinker formations, where present, plough up the fuel bed at the walls and bare the grate surface. When this happens the surface is exposed to the full furnace temperature and, in time, will be burned and require frequent replacement. Furthermore, because of the reduced resistance, in the exposed areas, a considerable quantity of excess air will find its way into, and materially lower the $CO_2$ content of the furnace gases at the side walls. This reduction in $CO_2$ content means an increase in the amount of heat carried away by the stack gases and therefore a

reduction in operating efficiency. A $CO_2$ traverse of the gas stream at the boiler outlet, when side-wall clinkers are present, may show as much as 5 per cent difference between readings at the side wall and at center of the gas stream. In an effort to overcome this difficulty, it is necessary for the stoker operator to frequently slice the side walls to keep them clean. As these clinkers adhere tenaciously to refractory surfaces, the walls are damaged and require frequent repairs. In addition the fuel bed is disturbed and holes in the fire may result in reduced $CO_2$ in the boiler outlet gases. The frequent opening of doors also allows air to be drawn in from the boiler room, resulting in reduced operating efficiency.

The high side-wall type of air-cooled tuyeres was developed to aid in reducing the formation of these troublesome clinkers, by providing a relative-

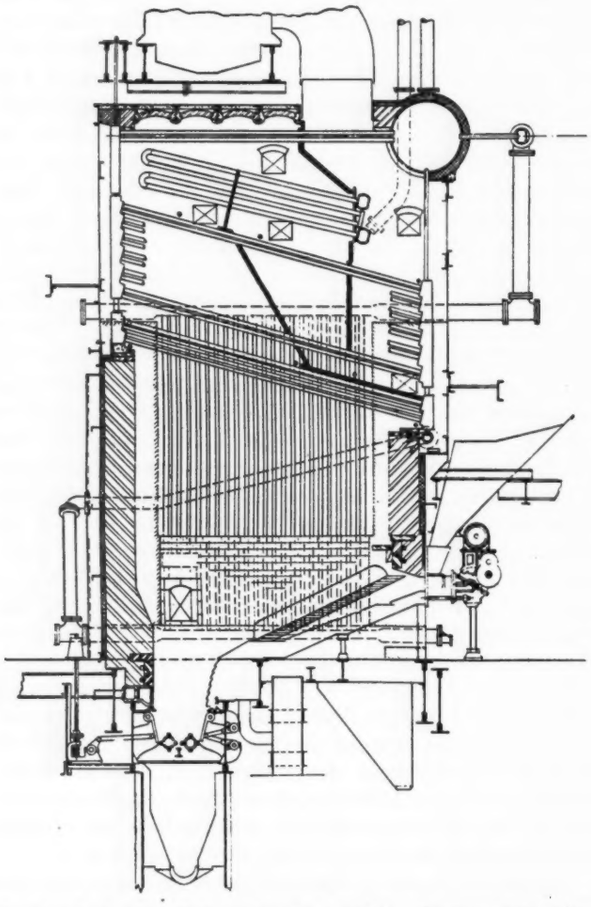

**Fig. 1—Early installation showing partial refractory wall above high side-wall tuyeres.**

ly cool surface in contact with the sides of the fuel bed. These tuyeres are provided with generous air openings so as to minimize burning. Their height corresponds to the average thickness of the fuel bed from the front to the rear of the stoker. Because of this fact, when the fuel bed is thickened up at the front end, it may come in contact with the refractory side walls, and clinkers will be formed. The tuyeres are then bared, as the clinker grows, and considerable air finds its way into the furnace without first passing through the fuel bed. Flame impingement occurs and localized heating will cause these tuyeres to be quickly burned. Thus they become a source of considerable maintenance.

The application of side-wall watercooling will serve to eliminate or make easy the removal of side-wall clinker formation. In addition to this, maintenance is practically eliminated because all refractory surfaces are removed from the zone of the fuel bed. It is then possible to eliminate the high side-wall tuyere and extend the grate surface to the side walls. A uniform fuel bed may now be maintained from side wall to side wall and, at the same time, the amount of manhandling and inspection is almost entirely eliminated. This construction is contrary to the design used in the early installation provided with water-cooled side walls. In Fig. 1 we have an illustration of one of these earlier designs of water-cooled, multiple-retort stoker settings. It will be noted that the side-wall refractories are carried to a height above the side-wall tuyere, to prevent the fuel bed from coming in contact with the water-cooled surface at all times. The reason for this is to prevent the cooling of the fuel bed at the sides. It was thought that this chilling effect would be sufficient to retard combustion, at the sides, to a point where material loss in carbon to the ash pit would result. In later installations the high side-wall tuyeres were retained and the refractory practically eliminated. An installation having this design characteristic is shown in Fig. 2. No increase in ash-pit loss was noted. As a result of this experience, it was decided to eliminate entirely the side-wall tuyere and carry the watercooling down to the normal grate line. A number of installations of this latter type indicated that with the proper design of grate surface, the fuel bed could be completely burned, even though in contact with the water-cooled, side-wall surface. This type of construction, therefore, overcomes the earlier design disadvantages and makes possible more uniform operating results.

The amount of side-wall cooling to be provided in any given installation will depend on a number of variable factors, of which furnace size liberation rates and type of fuel are the most important. Where the furnace is large and the heat liberation rate relatively low, four or five rows of tubes, paralleling the stoker surface, will be sufficient. Where the furnace is small and the fusion temperature of ash in the coal is low, it may be necessary to entirely cover the side walls so that the furnace temperature may be maintained sufficiently low to prevent the formation of slag deposits in the boiler tube bank. Where a poor grade of coal is burned, in nearly all instances, the atmosphere in the furnace, due principally to the presence of sulphur and iron, will cause extreme erosion of the refractories. This source of maintenance is almost entirely eliminated by the installation of completely water-cooled walls.

Furnace wall construction may be divided into two general classifications, the bare-tube and the protected-tube types.

The bare-tube type of construction may be defined as one in which the wall is composed of plain bare tubes. The cooling surface, in this case, is directly exposed to furnace temperature and is capable of absorbing heat at an extremely high rate. The simplest form of construction consists of plain tubes, spaced on uniformly close or wide centers, and covering the area of furnace wall that needs protection. The tubes usually terminate in headers. Downcomer tubes from the boiler supply the water to the lower headers. Riser or relief tubes extend from the upper headers to the boiler drums.

The protected-tube type of construction may be defined as one in which the wall is composed of tubes which are protected on the furnace side by castings. These castings may be bolted, shrunk or cast onto the tube surface.

In the case of the "bolted-on" type of construction, the tubes are accurately lined on relatively wide centers. Cast iron blocks, in which the tube seats are accurately ground, are then bolted to the tubes with plastic bonds of high heat conductivity between the block and the tubes. Considerable care must be exercised in the erection of this type of wall in order to secure good contact between the tube and block and to minimize burning of the cast surface. Because it is impossible to maintain full contact between the block and the tubes at all times, a resistance to the heat flow is set up between the exposed surface and the water. As a result, this type of construction is capable of absorbing approximately one-fourth the amount of heat per square foot absorbed by the bare-tube type of construction.

In the type of construction using the "shrunk-on" block, the blocks themselves are bored to gage, heated and shrunk onto accurately gaged seamless tubes. Here again we have a type of construction which depends on mechanically-maintained contact for the transfer of the absorbed heat. When the blocks are brought up to temperature, in the furnace, they expand and do not grip the tubes as tightly as when cold. As a result a heat gap is set up with the resultant lowering of the rate of heat transfer to the water contained in the tubes. However, the extent of this heat transfer rate may in time reach one-half that possible with the bare-tube type.

The third and most important type of protected wall construction is the one using the "cast-on" type of block. In this case the furnace side of the tube has a flat cast-iron surface which is actually integral with the tube. The blocks are cast onto the tubes by a temperature control process. An actual weld occurs where the cast iron joins the tube eliminating the possibility of any heat gap. While the outward appearance of this wall is similar to that of the "bolted-on" block type, it has the feature of almost as high heat absorption as the bare-tube type. It has also the added feature of not requiring any type of panel casing construction to make the rear of the tube accessible for repair and maintenance. These tubes may be set in front of a solid refractory wall, thereby eliminating costly and special supporting steel for side-wall supports. This is particularly true where the horizontal type of wall is used at the sides of stokers. Furthermore, erection costs and time for installation are reduced because each tube and its blocks is shop-assembled.

In deciding on the type of water-cooled construction to be used in connection with a stoker-fired installation, consideraion must be given to first cost, maintenance, and the ability of the wall to provide the necessary degree of wall protection. The relative heat absorbing capacities of the different types of construction is also a factor which should be evaluated. Both the bare tube or the cast-on block type of protected tube meet all of these requirements, and therefore are the yardsticks for measuring any other constructions. A simple and quick check on the effectiveness of any wall is the number of downcomer and riser tubes provided. The area of these tubes is dependent on the area of the wall exposed, the effective water head on the wall, and the amount of heat absorbed. It will thus follow that the most effective wall will be the one with the greater number of downcomers and risers.

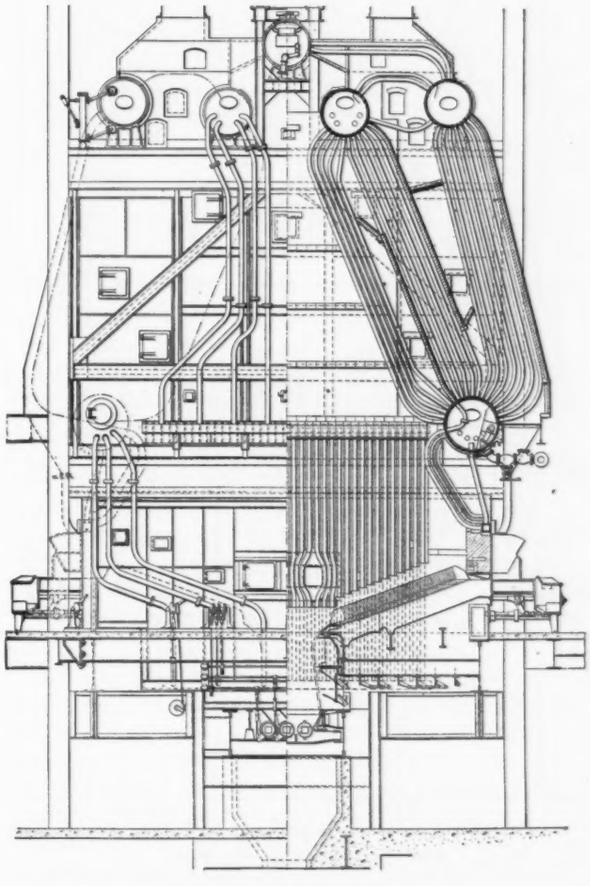

**Fig. 2—Water-cooled side walls with high side-wall tuyeres and refractory practically eliminated.**

When considering the installation of horizontal wall screens, along the sides of a stoker, the question of ample downcomers and risers is of great importance. These screens have a relatively slight

slope, and therefore a low head, to provide the necessary circulation. Unless the upper or outlet header is sectionalized and a riser provided for each two or three horizontal tubes, recirculation and stagnation is liable to occur. As a result of this, the tubes will blister and burn in a very short time. By sectionalizing the outlet header, circulation is speeded up and danger from failure is eliminated. It has been the general practice, where the bolted-on block construction is used, to cut down the number

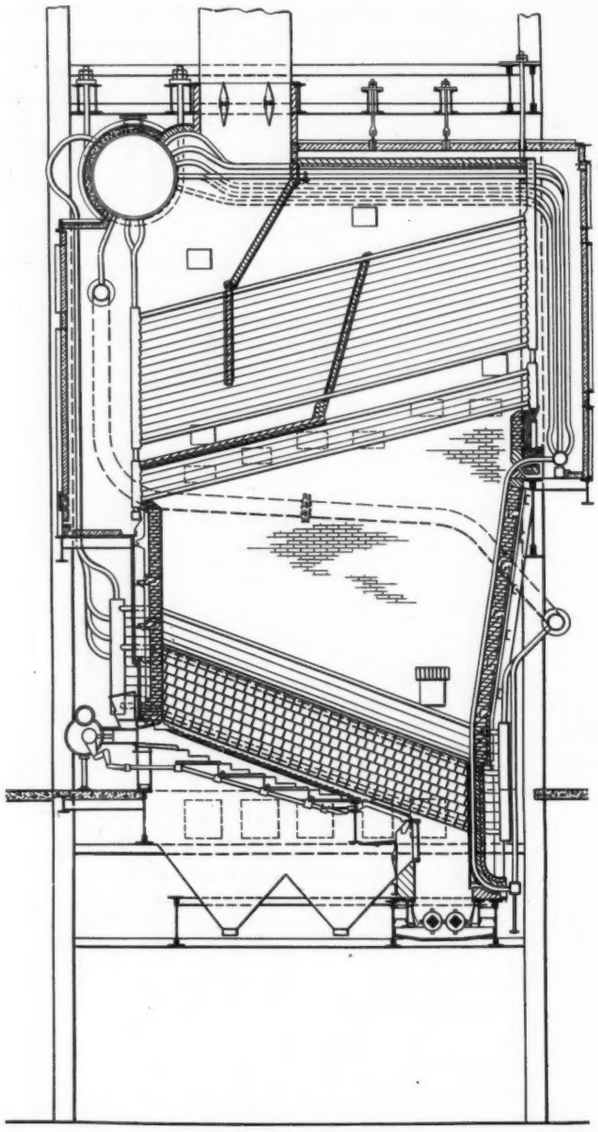

**Fig. 3—Combination cast-on block and bare tube construction with inclined type side wall.**

of downcomer and riser connections, because of the reduced capacity of this type of wall as a heat absorber. However, should a block become loosened or burned, the supporting tube will be blistered and rupture in a very short time. The outage and cost of replacement, because of this failure, will more than pay for the additional risers and downcomers required to insure adequate circulation.

In order to indicate more clearly the possible variation in the amount of wall cooling provided for multiple-retort stoker installations, a number of illustrations is presented.

The sectional header boiler installation, shown in Fig. 3, is designed to burn a good grade of bituminous coal, at moderate combustion rates. The boiler is set relatively high and therefore ample furnace volume is available. Along the furnace side walls a horizontal arrangement of water-cooled surface is provided, composed of eleven rows of tubes on 7-inch vertical centers. The lower seven rows are of the cast-on, integral-block type and provide a smooth surface along which the edges of the fuel bed pass. The upper four rows are composed of bare tubes. Four downcomer and six riser tubes are provided to insure rapid and adequate circulation at all times. The rear wall consists of vertical tubes on 7-inch horizontal centers. The lower ends of these tubes are armored with integral, cast-on blocks to a height corresponding to the armored side wall. The upper portion of the tubes is bare. This type of wall is capable of high rates of heat absorption, thus serving to lower materially the furnace temperature and at the same time reducing furnace refractory maintenance to a very low figure.

The bent-tube boiler installation shown in Fig. 4 is provided with side and rear watercooling. In this instance, the tubes are installed vertically and completely armored. The bolted-on type of block is used. As a result it is necessary to provide a paneled type of wall construction so that renewals of the wall blocks may be accomplished with a minimum cost. This type of construction is costly because of the field labor involved in proper erection of the wall, and also because it is necessary to provide the insulated panel casing instead of the solid refractory type of construction. As a cooling medium this wall is approximately 33 per cent as effective as the bare-tube type. Its effect in lowering furnace temperature is less than in the construction shown in Fig. 3.

In Fig. 5 is shown what may be considered a modification and improvement of the design in Fig. 4. In this instance we have a water-cooled rear wall, the lower section of which is provided with cast-on integral blocks, while the upper section is of bare tubes. The upper ends of these rear wall tubes are expanded into the lower end of the boiler header. The wall thereby becomes a really integral part of the boiler unit. The side-wall cooling surface is composed of vertical tubes. The lower ends of these tubes, for a short distance above the grate line, are provided with cast-on blocks so that a smooth surface is presented to the fuel bed sides. The upper ends of the side wall tubes are bare and exposed to full furnace temperature. The cooling effect on the furnace gases of this type of construction is considerably greater than that of the construction shown in Fig. 4. Because of the block design used, the side walls may be constructed of solid refractory. The rear wall is of the paneled, suspended type because of the slope made

necessary by the difference between the furnace depth and stoker length.

The use of water-cooled furnace linings with the single-retort type of underfeed stoker, has been limited to a very few installations. The principal reason is that the boiler units are small in the majority of cases, and the actual maintenance cost of furnace repairs is so low that it is not always possible to justify the first cost. However, where the fuel cost is high and continuity of service is a controlling factor, serious consideration must be given to providing a type of furnace lining which will require practically no repairs. In Fig. 6 is illustrated an installation of this type which has been in satisfactory operation since 1929. The boiler is of the straight-tube, box-header type and is fired by a single-retort, underfeed stoker. The fuel is Ohio bituminous coal which has a relatively low fusion temperature of ash and a high sulphur content. The water-cooled furnace linings are installed to prevent clinker formation at the dump plate line, and to eliminate fluxing of the refractories in the upper part of the furnace. These linings consist of 4-inch tubes, spaced on 7-inch horizontal centers, extending from the ash pit along the furnace side walls and through the boiler roof. In order to do this the actual furnace and first pass width of the boiler was increased 9 inches. The lower portion of the tubes, from the header to a point 12 inches above the dump grate level, is armored with

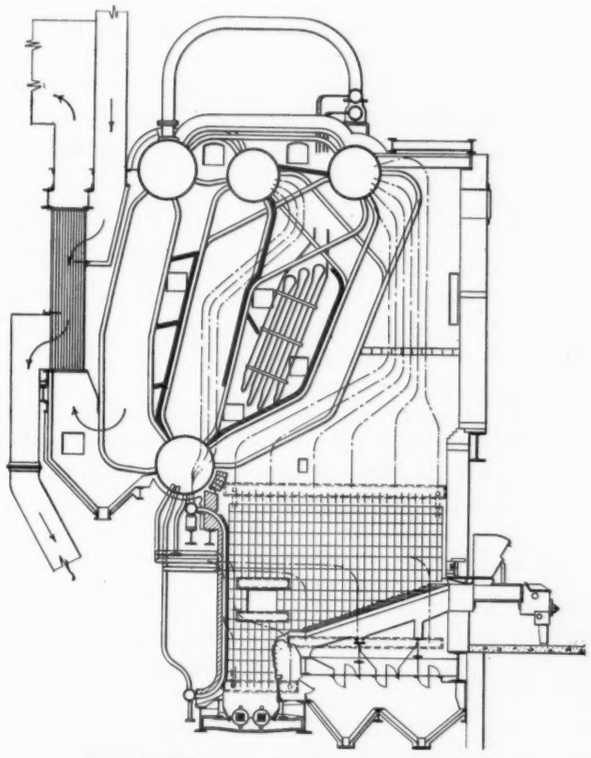

**Fig. 4—Bolted-on block wall construction.**

cast-iron blocks. The upper portion of the tubes is left bare so that the maximum wall-cooling effect may be obtained. This type of construction is extremely simple and relatively inexpensive, yet, at the same time, it is very effective in accomplishing the purpose for which it is installed.

Frequently the question is asked, "Will the installation of water-cooled furnaces serve to increase the

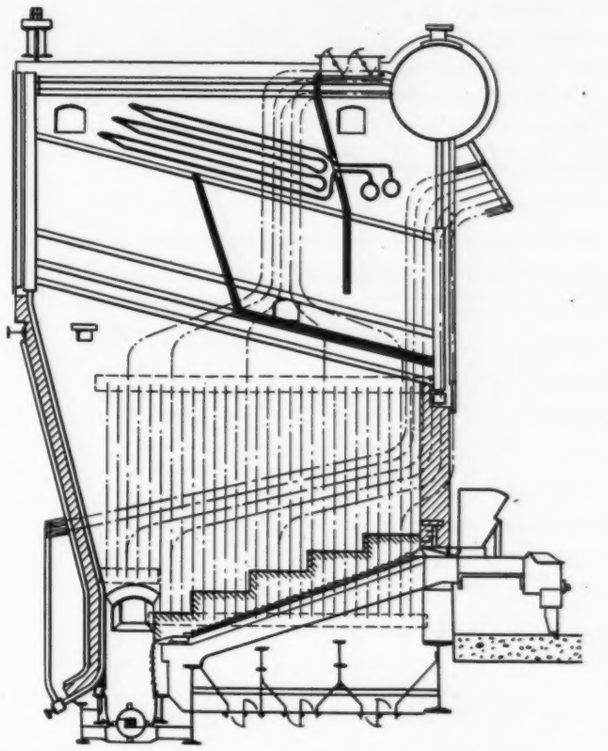

**Fig. 5—Combination cast-on block and bare tube construction with vertical type side wall.**

capacity of an existing stoker-fired unit?" The answer to this may be either yes or no, depending on certain operating factors.

A water-cooled furnace makes it possible to develop the full fuel burning capacity of a stoker, provided sufficient draft is available to remove the resulting products of combustion. In installations where this capacity is not developed (because of high stoker maintenance) it is possible to increase the steam output, by the addition of properly designed cooling surfaces. In other instances the full fuel burning capacity of the stoker may not be developed, because a high percentage of excess air is used to lower the furnace temperature and preserve the refractory lining. This results in an increase in the boiler draft loss, to a point where any further increase in output would require operation with pressure in the furnace. At the same time the increase in excess air serves to lower the overall efficiency of the unit. By providing a suitably water-cooled furnace, it is possible to reduce the excess air requirements to a minimum, and thereby reduce the boiler draft loss and increase the efficiency. It now becomes possible to increase the rating, of the unit, by an amount equivalent to the difference in draft loss and efficiency, between the condition of excessive and normal excess air.

When a stoker is operating at its full burning capacity, or when the entire amount of available

draft is being used, the simple addition of furnace wall-cooling will not serve to increase the capacity of the unit. The fact that this surface is located in the furnace, and is capable of absorbing heat at a high rate, does not mean that the heat so absorbed is added to that absorbed by the boiler, prior to waterwall installation. The wall surface simply serves to increase the rated capacity of the unit, and thereby reduces the actual work done by the boiler. Because the rated capacity of the unit is increased, by an amount equivalent to the amount of surface

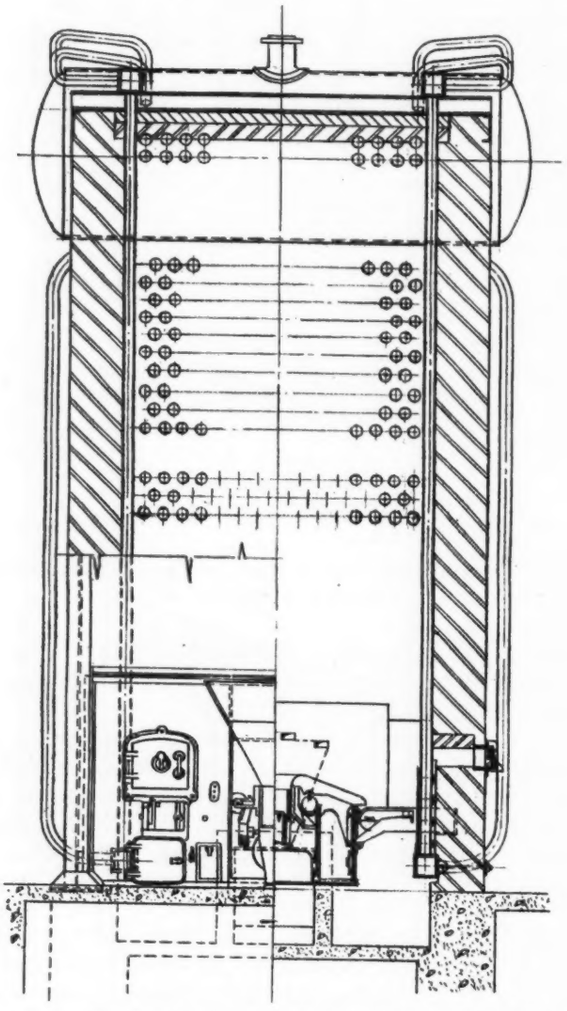

**Fig. 6—Combination block and bare tube wall in setting fired by single-retort, underfeed stoker.**

installed in the furnace, the boiler outlet temperature is reduced to correspond to the actual rating, on the combined boiler and furnace. This point is best illustrated by an example. Assume a 750 hp. boiler is equipped with an underfeed stoker and has an outlet temperature of 625 deg. fahr. at 250 per cent of rating or 1875 developed horsepower. Now assume that this same boiler has 800 sq. ft. of water-cooled surface added in the form of furnace-cooling, and that the rating is still equivalent to 1875 developed horsepower. The actual rated capacity of the reconstructed unit is 750 plus 80 or 830 hp. The actual rating at which the unit is now operating is 225 instead of 250 per cent, and the exit gas temperature is reduced, in an amount, corresponding to the reduction in rating. This reduction in boiler exit gas temperature serves to increase slightly the efficiency of a unit when watercooling is added. Furthermore, because the external furnace-wall temperatures are also reduced, the loss due to radiation is thereby decreased. Due to the reduction in dry gas, moisture and radiation loss, the resulting gain in efficiency should be credited to the installation of the waterwall, and evaluated in terms of fuel dollars saved. This saving, combined with that, accruing from reduced outage and maintenance, will indicate whether wall cooling is an asset or a liability.

From the foregoing discussion it will be realized that definite benefits may be derived from the application of properly designed waterwall to a stoker fired furnace. However, careful consideration must be given to the amount, location, and type of cooling surface, to be installed. In every case the use of the bare-tube wall or the cast-on block construction will give more real cooling effect, per sq. ft. of installed area, than any other type of construction. Therefore, less surface is required to produce the same result, and the saving in first cost and lowered maintenance makes the installation more economically justifiable.

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**Beck Engineering Combustion Kompany,** with offices at 4525 North Euclid Avenue, St. Louis, Mo., is a new company organized by Vernon S. Beck who for the past five years was chief engineer for the Sonner Gas Burner Company of Winfield, Kansas.

The new company will offer an extensive line of burners including types similar to those already on the market as well as burners manufactured under new patents. Five general types will be offered in numerous sizes. All the burners will be made of a special Hi-temp-alloy. The company will also specialize in making burners to specifications of boiler and furnace companies.

Mr. Beck holds degrees in mechanical and electrical engineering. Before he joined the Sonner organization he was engaged in the engineering construction business in Minneapolis.

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**American Boiler Manufacturing Association** will hold its annual convention at the Greenbrier Hotel, White Sulphur Springs, West Virginia, on May 23 to 25.

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**The Neckar Company, Inc.,** 67 Wall Street, New York, has received an order from The Sinclair Refining Company for the installation of the Neckar Process of Boiler Feed Water Treatment in its Coffeyville, Kansas, Refinery. The system can treat 317,000 lb. of raw water per hour.

# Electrical Methods Proposed for Preventing Scale and Corrosion in Steam Boilers

By WM. L. DEBAUFRE

Chairman, Department of Applied Mechanics, The University of Nebraska

**The author presents a valuable and comprehensive discussion of a subject about which steam plant engineers in general have relatively little knowledge. The theories and principles involved in the numerous methods proposed for the electrical prevention of scale and corrosion are explained and the operation of some of the principal methods is described. Certain of these methods were investigated under the supervision of Mr. DeBaufre, and the results of these investigations are given.**

FOUR electrical methods proposed for preventing scale and corrosion in steam boilers have been investigated during the past several years by the Technical Research Department of International Combustion Engineering Corporation. These four methods are known as the Nee-wat system, the Kirkaldy system, the Hauptvogel system and the Agfil system. In view of the present interest in the subject by a sub-committee of the National Electric Light Association, it was thought desirable to publish the results of the investigations although the data are now several years old. A bibliography of United States Patents on the subject has been brought up to date and a list of the more important patents is appended to this article.

In investigating the four systems mentioned, it was attempted to find reasonable explanations for the results claimed. These reasons will be first submitted in a discussion of all the methods proposed in the various patents on the subject before describing the performances found for the four systems investigated.

### *Discussion of Methods Proposed*

The earliest patent found to have any bearing on this subject is No. 22,271 issued to Lloyd in 1858; but the purpose was to prevent an explosion of the boiler rather than scale or corrosion, as indicated by the following statement in the Patent Office Report: "This invention consists in placing within a steam boiler a metallic conductor made to communicate with the outside, for the purpose of maintaining an electrical equilibrium between the inside of the boiler and the outside thereof, and thus preventing the explosion of the boiler when the water becomes low and the plates unduly heated." In view of our present knowledge of electrical phenomena, this statement appears ridiculous. The same thing might be said of a number of the other early patents.

Thus, Patent No. 50,774 covers "metallic points of a conductor to collect whatever electricity there may be generated within the boiler, and conduct through the rod and its connections to the shell of the boiler, thus preventing the crystallization of the calcareous deposits generated in evaporating water." Another early patent, No. 62,093, proposes the use of inverted lightning rods in the steam space of a boiler for the same purpose. Magnetic methods of preventing incrustation were proposed in a number of early patents, such as Hay's patent No. 140,196. The more reasonable methods proposed for preventing scale and corrosion are based on electrolytic effects of the electric current.

Corrosion of steel has long been recognized as due to electro-chemical activity. If at two different points connected by both metal and solution there are different degrees of strain in the metal, or different materials, or even different concentrations of oxygen or of substances dissolved in the solution, the entire arrangement constitutes a discharging electric battery, at the anode of which dissolution of metal takes place. The strained part of the metal will be an anode because its dissolution will take place with decrease in energy content of the system.

For many years, zinc slabs have been placed within steam boilers, particularly in marine service, for reducing pitting and corrosion. Zinc is electro-positive to iron, so that an electric current flows from the zinc through the water of the boiler to the steel shell and tubes and thence back to the zinc, which should be in good metallic contact with the shell or tubes. The zinc anode is corroded away by electrolytic action in protecting the boiler shell and tubes which become the cathode of the zinc-iron battery. Various modifications in the use of zinc have been proposed in a number of patents. Some of these patents cover improved means for holding the zinc slabs or bars, see patent No. 999,-108, but other patents are evidently based on

erroneous ideas of the action of the zinc in preventing corrosion.

In place of using zinc, similar electrolytic action may be produced by suspending in the boiler water an electrode insulated from the shell and tubes and then imposing a potential difference from a direct current circuit between the electrode and the boiler shell and tubes so as to make the electrode an anode electropositive to the shell and tubes as cathode. Such an arrangement should evidently reduce, if not eliminate corrosion, although it has been questioned whether local electric currents cannot persist even when the whole boiler becomes a cathode.

This arrangement was apparently first patented in the United States in 1869 by M. G. Farmer. The first claim in his Patent No. 88,285, reads: "Passing a current, or series of currents, of positive electricity, from a conductor of the same electrical character as the boiler shell, and suspended in the water of the boiler, through the water, to the boiler-shell, by connecting the suspended conductor with the positive pole of a battery, or other source of electricity exterior to the boiler, while the boiler shell is connected with the negative pole of said battery, the purpose being to prevent the corrosion and incrustation of the boiler, as specified."

It will be noticed that the above claim not only states the purpose to be prevention of corrosion but also of incrustation. The same purposes are stated today for the Kirkaldy system investigated, which works upon the same general principle of passing a direct current from an insulated electrode through the water to the boiler shell and tubes. Not only is new scale claimed to be prevented, but it is said that old scale is loosened when the system is applied to a boiler. A satisfactory explanation for prevention of scale and incrustation is not so apparent as for prevention of pitting and corrosion. Any theory of scale prevention by this method must correspond with the theory of scale formation accepted.

When generation of steam occurs in a boiler, the concentration of calcium and magnesium salts increases until supersaturation is reached. Supersaturation alone may account for the formation of scale on the heating surfaces, for the calcium sulphate, magnesium carbonate, etc., may simply deposit on surfaces adjacent to the places where supersaturation occurs in the boiling water. It is possible, however, that when supersaturation occurs, the salts of calcium and magnesium are precipitated within the solution as a colloid which becomes electrically charged for some reason, such as the setting free of energy by the formation of colloids from the ions originally present in the solution, "frictional electricity," etc. These colloids may then be plated on the metal surfaces by electric currents due to electrolysis or other causes.

If we accept the above "colloid theory of scale formation," then we might explain scale prevention by the Kirkaldy and similar systems, as due to plating of scale forming materials on the anode suspended in the boiler water rather than on the boiler shell and tubes which become a cathode. Instead of acting in this way, however, the applied electromotive force might neutralize the electrically charged colloidal particles so that these particles coagulate and remain as a sludge in the water rather than deposit as scale on either the insulated electrode or the boiler shell and tubes.

Whether or not we accept the "colloid theory of scale formation," we might explain any prevention of scale formation or any loosening of scale already formed as due to the mechanical effects of liberation of gas or of adsorption of other substances on the metal surfaces through electrolytic action when an electric current flows from a suspended electrode through the water to the shell and tubes.

L. O. Gunderson, Chief Chemist of the Chicago and Alton Railroad, considers that adding arsenic to water within a boiler is as necessary as impressing a direct electromotive force between an electrode suspended in the boiler water and the boiler shell and tubes. His process is covered in Patent No. 1,449,991 and is discussed in his article entitled "Corrosion An Electro-Chemical Phenomenon," in the Railway Review for Sept. 4, 1926. His explanation is that the arsenic is first deposited on the boiler shell and tubes by electrolytic action and then hydrogen is deposited on the arsenic. Hydrogen upon arsenic has a much higher discharge potential than upon iron; sufficiently higher to counteract all local action which would occur if the arsenic were not present in spite of the boiler shell and tubes being a cathode. This system has not been investigated.

Instead of passing a direct current from the suspended electrode through the water to the boiler shell and tubes, it has been proposed to utilize an alternating current which flows first in one direction and then in the other to prevent corrosion and the deposition of scale. This was proposed by M. Kotyra in Patent No. 392,736, issued in 1888. Such use of an alternating current is also one feature of the Nee-wat system investigated.

It is not easy to see how an alternating current between the electrode and the boiler shell would reduce corrosion because the alternating current would be superimposed on any direct current due to dissimilar metals, etc., which would remain as a net effect in one direction of the total current which flows first in one direction and then in the other direction. If, however, electrolytic corrosion is subject to a hysteresis effect such that a direct electromotive force has to operate a short time in order to start corrosion, then rapid alternation of the impressed electromotive force might make the time of uni-directional action shorter than that required to start corrosion.

If the deposition of scale is the result of electroplating colloids from supersaturated boiler water, as surmised above, then for similar reasons the deposition of scale might be reduced by impressing an alternating electromotive force between the electrode and the boiler shell and tubes. This might, for instance, be the case if there are hysteresis effects such that a direct electromotive force has to act for a short time to start deposition of scale.

Then, the rapid alternation of the imposed electromotive force might make the time of action in one direction shorter than that required to start deposition of scale. Instead of acting in this way, it is also possible that the applied alternating current might neutralize the electrically charged colloidal particles so that these would coagulate and remain as sludge in the water rather than deposit as scale on the metal surfaces.

Or, the application of a strong alternating electromotive force between the electrode suspended in the boiler water and the boiler shell might affect the deposition of scale for mechanical rather than electrical reasons. Thus, the liberation of gas or the adsorption of other substances through electrolytic action might physically prevent the scale from adhering to the metal surfaces. Such an explanation might also account for loosening of scale already formed when the alternating current is applied, as is claimed for this process.

The passing of an electric current through the metal of a boiler from one point to another on the boiler shell rather than from an insulated electrode through the water to the shell, was proposed by A. T. Hay in his patent No. 59,768, issued in 1866. In another patent, No. 59,910, also issued in 1866, Hay proposed the same method to prevent incrustation in evaporating pans. "Limiting the electric current so that it has a magnitude less than that sufficient to produce a drop of potential across said object high enough to decompose the said liquid" was claimed by Thalhofer in patent No. 1,558,646. Elmore and Creighton in patent No. 1,576,581, claimed "maintaining potential gradient below that which will accelerate normal electrolytic corrosion while maintaining a cross-sectional density of current in the body whereby encrustation and scaling of the surface will be eliminated."

A direct current passing through the metal of a boiler shell and tubes will produce a drop in potential from point to point in the metal. It would therefore appear that current would flow through the water of a boiler from a point of high potential to a point of low potential on the metal of the boiler shell and tubes. Dissolution of the metal would occur at the point where the current leaves the metal and enters the water. In order for an electric current to flow through the water, however, a certain counter electromotive force must be overcome, the value of which depends upon the composition of the impurities in the boiler water, polarization, etc. While the flow of electric current might be kept sufficiently low to maintain the potential gradient of the impressed electric current below the value of this counter electromotive force, there might be local potential gradients due to strains, etc., which would be accentuated by the impressed potential gradient. Local pitting and corrosion at some points might therefore be increased by a direct current passing through the metal of the shell and tubes of a boiler.

Instead of a steady direct current, a pulsating current was proposed by Thalhofer in patent No. 1,558,647 and also by Creighton in patent No. 1,611,853. The same remarks apply to a pulsating current as to a steady current except that the effects in accelerating corrosion might not be so great with the pulsating current.

The patents of Elmore and Creighton were assigned to the Antiscale Corporation of Philadelphia and are undoubtedly the basis for their system, which was not investigated. Thalhofer's patents are the basis of the Agfil system, which was investigated. Passing a direct current through the metal of a boiler is also the basic feature of the Hauptvogel system investigated. In the Nee-wat system investigated, an alternating current is passed through the metal as well as from an insulated electrode to the metal of the boiler shell and tubes.

An alternating current flowing through the metal of the boiler shell and tubes might be more effective in reducing corrosion than a direct current if corrosion is subject to a hysteresis effect as surmised previously. Should, however, the local direct current flow at right angles to the impressed alternating current, it is apparent that the direct current would not be affected, so that corrosion in this case would not be reduced.

Any generation of gas or other mechanical effect of electrolysis produced by a steady or pulsating direct current or an alternating current flowing through the boiler shell and tubes, might reduce scale formation. Or, if scale formation be due to electroplating of colloids on the metal surfaces, this might be affected by variation in the electrical charges in the metal or the boiler water due to currents flowing therein.

There may be other factors than those discussed above, to account for corrosion and scale formation in steam boilers as an electrical phenomenon which would be affected by the application of a direct or an alternating current through the metal or the water. In any such application, however the complicated arrangement of tubes, drums, etc., in a modern steam boiler would make it practically impossible to obtain a uniform effect of the impressed electrical current throughout the whole structure.

Instead of attempting to prevent scale formation in steam boilers by the direct application of an electric current to the boiler shell or to the water contained in the boiler, it has been proposed by a number of inventors to purify the feedwater electrically before it enters the boiler. Patent No. 1,080,826 is of particular interest as covering the treating of feedwater both electrically and chemically in a feedwater heater. This patent was assigned to the Harrison Safety Boiler Works, which has since become the Cochrane Corporation. It is significant that this company is a prominent manufacturer of feedwater heaters but does not offer electrical treatment of the feedwater in connection therewith. Electrical treatment of the feedwater before entering the boiler is one of the features of the Nee-wat system investigated.

The "colloid theory of scale formation" would not, of course, account for any deposition of scale forming materials by electrolysis in a feedwater

heater where supersaturation is not reached. Neither will the calcium, magnesium, etc., be plated out as metals because the voltages required are much higher than for the liberation of hydrogen, which will occur at the cathode while oxygen is set free at the anode. It is possible, however, that the alkalinity resulting from removal of hydrogen ions at the cathode might precipitate iron, magnesium and aluminum as hydroxides. Such alkalinity might also convert bicarbonate ions into carbonate ions, with the result that the latter would precipitate as calcium carbonate on account of the lower solubility of the normal carbonate. Such alkalinity might also cause the precipitation of magnesium or calcium silicate. Silicic acid might be precipitated at the anodes on account of acidity caused there by removal of hydroxide ions. The relatively slow speed of purely chemical reactions between precipitates and solution, might then prevent redissolution of these precipitates by chemical action as the water flows past the electrodes. A high temperature would aid in dehydration of the precipitates.

Even if sludge were thus formed indirectly by passing an electric current through the feedwater, this method would not be generally applicable to all types of boiler feedwater. For instance, if the water contained calcium sulphate only, enough of this salt would remain in solution in the water to form scale within the boiler because the solubility of calcium hydroxide is sufficiently great to prevent much of it precipitating from alkalinity at the cathode. Also, if the feedwater contained a large amount of sodium salts, including the carbonate, these would not be removed. The boiler water would then perhaps be alkaline enough to cause embrittlement of the boiler steel. If it were highly conducting, this would aid in corrosion where strains or oxygen are present.

Patents 1,003,604 and 1,055,327 apply to the electrolytic protection of underground structures and patents 1,020,480 and 1,699,974 and 1,816,487 apply to steam condensers rather than steam boilers. These patents are included in the list, however, for their general interest. Patent No. 1,308,040 is also included for the same reason, one claim being: "The method of increasing the energy developed in liquid heating devices that comprises establishing a difference of electric potential between the said liquid and its container while the latter is being heated." This appears a very broad claim in view of the many patents which have been issued on electrolytic methods of purifying water and of preventing scale and corrosion in steam boilers. Only about one-third the total number of patents found to have some bearing on the subject have been included in the list appended to the article. Most of the unexpired patents cover details of constructing and supporting the electrodes within the boiler, of insulating the electrodes from the boiler shell, of arranging the electrical circuits to obtain a low potential difference, of connecting the metal of the boiler in the electrical circuit, etc., the more fundamental principles having been longer known. Some claims in the latest patents are apparently too broad.

A systematic investigation was not attempted of all the electrical systems proposed in the patents listed for preventing scale and corrosion in steam boilers, but the investigation was limited to the four systems brought to the attention of the Company. These four systems will now be discussed.

### *Nee-wat System*

The inventor of this system is G. S. Neeley, one-half of the interest in the patents being assigned to G. Watkins. The Nee-wat system was investigated in 1927. At that time Mr. Neeley was interested in two systems which he designated as the "internal system" and the "external system."

In the "internal system," direct current was first contemplated, as indicated in patents No. 1,579,453 and No. 1,579,454. Later a pulsating and then an alternating current was considered preferable, as proposed in patents No. 1,773,274 and No. 1,773,275. One terminal of a 110-volt alternating current generator was connected to a distributor set on insulators at the bottom of the steam drum of a water-tube boiler while the other terminal was connected to the blow-off pipe. By means of a transformer, a second alternating current 180 degrees out of phase with the first one, was made to flow through the metal of the entire boiler under a potential drop of two or three volts by connecting the terminals of the transformer to the top of the steam drum and the blow-off pipe respectively. A diagram of this system is shown in Fig. 1.

Neeley claimed that the use of his "internal system" prevented the formation of scale and loosened

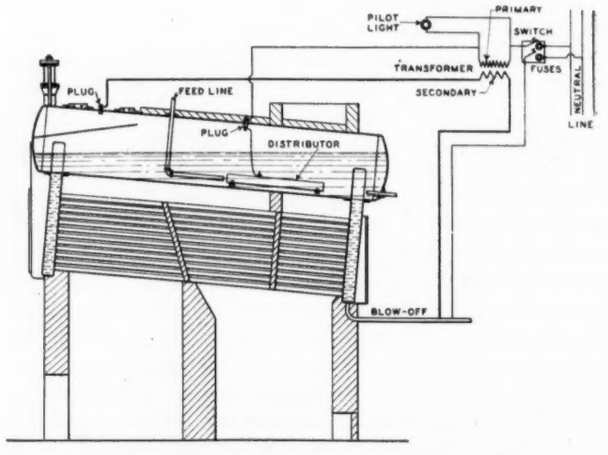


**Fig. 1—Diagram showing arrangement of Nee-wat system.**

that already in a boiler, but a non-settling sludge was formed which remained in the steam drum instead of collecting in the mud drum where it could be removed by blowing down. His next thought was "if thermo-electric currents plate out these salts, why not plate them out by a direct current before entering the boiler?" This led to the "external system."

Neeley's "external system" as inspected at the

plant of the International Shoe Company's tannery at Hartford, Illinois, was installed in the shell of a feedwater heater, about 30 in. in dia. and 6 ft. high, from which the steam heating coils had been removed. Mounted within this shell were electrodes, consisting of two horizontal "duriron" plates serving as anodes and several wire screens as cathodes between the plates. The lower anode was set on insulation about two feet above the bottom of the shell. It was about 24 in. dia., one-half inch thick and was perforated with one-half inch holes. A wooden cross on this anode plate supported several ten-mesh wire screens spaced about an inch apart to serve as the cathode. Electrical connections to anode and cathode were made by means of insulated wires passing through the shell. The feedwater entered the shell near the bottom through a horizontal pipe from the hot well and was heated up to the boiling point by the addition of live steam. The outlet was at the side of the shell near the top. At the top of the shell was a valve for removing non-condensable gases.

Samples of the raw water, of the treated water and of sludge from the electrodes, were analyzed by the Pittsburgh Testing Laboratory and also by the Hall Laboratories with the results given in Table I. The first set of values were obtained by the standard procedure for calculating the results of water analysis in which the various negative ions are distributed among the positive ions in an arbitrary manner and no distinction is made between carbonate and bicarbonate. In the second set of values, the proportions of the separate ions are given including the carbonate and bicarbonate ions. By special request, the Pittsburgh Testing Laboratories reported that all the $CO_2$ present was as bicarbonate in both the raw and treated water. This may, of course, have been due to the samples taking up $CO_2$ from the air. They also reported no sulphate in the sludge. This additional information makes the two sets of data in fair agreement.

TABLE I.—ANALYSES FOR NEE-WAT SYSTEM INSPECTED. MADE BY PITTSBURGH TESTING LABORATORIES.

| Constituent Compounds | Raw water, parts per 100,000 | Treated water, parts per 100,000 |
|---|---|---|
| Calcium carbonate | 8.00 | 3.28 |
| Magnesium carbonate | 3.27 | 1.69 |
| Calcium sulphate | 0.48 | 0.68 |
| Magnesium sulphate | 0.30 | 0.48 |
| Calcium chloride | None | None |
| Magnesium chloride | None | None |
| Sodium sulphate | 3.85 | 0.62 |
| Sodium nitrate | None | None |
| Sodium chloride | Trace | Trace |
| Silica | 2.04 | 1.92 |
| Iron oxide and alumina | 0.92 | 0.68 |
| Suspended solids | 1.60 | None |

Sludge

| | |
|---|---|
| Silicon | 4.44 per cent |
| Iron oxide | 0.91 per cent |
| Lime | 36.47 per cent |
| Magnesia | 13.23 per cent |
| Carbon dioxide | 44.92 per cent |

MADE BY THE HALL LABORATORIES.

| Constituent Ions | | Raw water: Parts per million | Raw water: Equivalents per million | Treated water: Parts per million | Treated water: Equivalents per million |
|---|---|---|---|---|---|
| Hydroxide | (OH) | 0 | 0 | 0 | 0 |
| Carbonate | ($CO_3$) | 8.0 | 0.27 | 0 | 0 |
| Bicarbonate | ($HCO_3$) | 98. | 1.61 | 74. | 1.21 |
| Sulphate | ($SO_4$) | 32. | 0.67 | 10. | 0.21 |
| Chloride | (Cl) | 4.0 | 0.11 | 3.5 | 0.10 |
| Phosphate | ($PO_4$) | 0 | 0 | 0 | 0 |
| Silica | ($SiO_3$) | 19. | 0.63 | 6.0 | 0.20 |
| Iron | (Fe) | 1.2 | 0.63 | 0.8 | 0.03 |
| Calcium | (Ca) | 25. | 1.25 | 17. | 0.85 |
| Magnesium | (Mg) | 16. | 1.31 | 4.9 | 0.40 |
| Sodium (calculated) | (Na) | 16. | 0.69 | 10. | 0.44 |
| Suspended material | | 1.6 | | 0.6 | |

Sludge

| | | |
|---|---|---|
| Sulphur trioxide | ($SO_3$) | 1.2 per cent |
| Carbon dioxide | ($CO_2$) | 20.9 per cent |
| Silica | ($SiO_2$) | 12.6 per cent |
| Ferric oxide | ($Fe_2O_3$) | 3.2 per cent |
| Calcium oxide | (CaO) | 25.9 per cent |
| Magnesium oxide | (MgO) | 13.5 per cent |
| Loss at 105 C. | | 1.4 per cent |
| Net ignition loss | | 21.5 per cent |

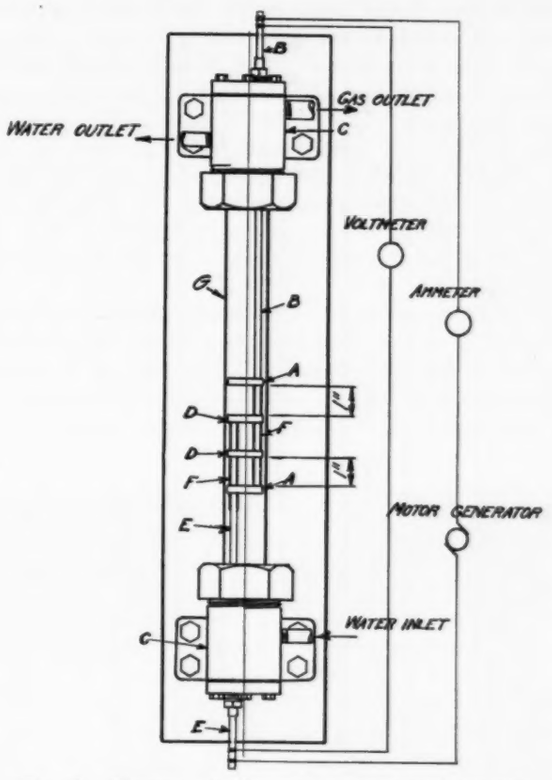


**Fig. 2—Diagram of Nee-wat experimental treater.**

By reference to Table I, it is seen that the treated water contains less scale-forming substances, such as compounds of calcium, magnesium and silicon, than the raw water. The sludge formed in the treater is probably a mixture of calcium carbonate, magnesium oxide or silicate, silica and iron oxide.

It was Neeley's idea that his "internal system" might possibly be used with his "external system" and that a filter would be employed to remove sludge from the feedwater after the external treatment.

In order to check experimentally the possibility of purifying boiler feedwater by Neeley's "external system," a treater approximately 1/500 the size of the apparatus inspected at Hartford, Illinois, was built and tested with two kinds of water, namely, a carbonate water similar to that at Hartford, Illinois, and a sulphate water similar to that available for boiler feedwater at Pittsburgh, Pa.

Referring to Fig. 2, the electrodes of the experimental treater were enclosed in a glass cylinder G. The two duriron plates A were welded to the duriron

rod B which passed through a stuffing box in the top header. The two copper plates D were located between the duriron plates and were soldered to the brass rod E passing through the bottom header. The rods were insulated by sleeves F from the water and the plates of opposite polarity. The rods were also insulated where they passed through the upper and lower headers C. Both the copper and duriron plates were 1¼ in. dia. and were perforated with five ¼-in. holes. The distance from the face of the duriron plate to the face of the copper plate was one inch. The water to be purified entered at the bottom of the treater, passed through and around the plates and then out at the top of the treater. Another opening at the top permitted any gases to escape to an external chamber. The electrodes were connected in an electrical circuit as shown in Fig. 2.

The experimental treater was connected as shown in Fig. 3 in the feed line to a small experimental boiler heated electrically. The treater E was in series with a feed tank B mounted on scales C, a plunger pump A and a feedwater heater D, all

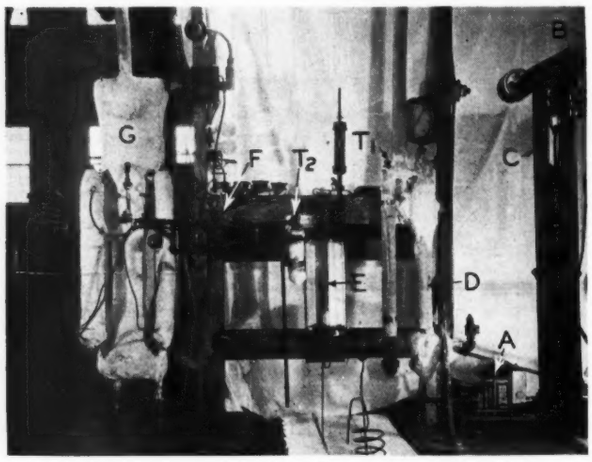


**Fig. 3—Nee-wat experimental treater connected to small boiler.**

located ahead of the treater. A sand filter F was located between the treater E and the boiler G. The temperature of the feedwater was measured at $T_1$ and $T_2$ before and after the treater as well as in the feed tank. Samples of the feedwater were taken for analysis from the feed tank B, after the feedwater heater D, after the treater E and after the filter F.

A series of runs was first made employing a synthetic sulphate water similar to that in the Pittsburgh district. The runs were made with direct current voltages from 25 to 135 volts and with the feedwater going through the treater at the rate of about 13.3 lb. per hr. per sq. in. of treater cross-section. This was approximately the same as the rate of flow through Neeley's treater at Hartford, Ill. The principal data are given in Table II. Each run was two to three hours in duration. The steam pressure was about 90 lb. gage and the temperature of the feedwater before the heater about 60 fahr.

While the system was in operation, small particles which looked like a precipitate could be seen through the glass cylinder. They were suspended in the water and were carried up the cylinder with the water current. Some of the particles lodged on the treater plates, but most of them passed on with the water. After several hours' operation, the treater plates were very dirty, but this had no effect upon the amount of current at the constant voltage.

After the first run at about 25 volts and the four succeeding runs at about 50 volts, the treater was taken apart and cleaned. The deposits were removed from the plates and it was found that the duriron electrode was being rapidly eaten away. Deposits were also collected from the filter and from the settling chamber between the feedwater heater and the treater. Analysis of the deposits are given in Table III. The large portion of sand ($SiO_2$) on the electrode probably came from sediment in the feed tank. The iron oxide ($Fe_2O_3$) came from rust in the tank and disintegration of the duriron electrode. As no $SO_3$ was present, the CaO and MgO came from the precipitation of calcium and magnesium bi-carbonates. Apparently the sand filter and also the sediment chamber in the pipe line after the feedwater heater were ineffective in collecting appreciable amounts of precipitate.

Referring to the data in Table II for the first six runs with the sulphate water and for voltages from 25 to 100 volts, a comparison of the chemical analyses of the water before and after the treater shows the treater to have been ineffective. The inconsistent variations in the chemical analyses are undoubtedly due to inaccuracies. The rate of flow through the heater was so small that it was impractical to take a sample sufficiently large for a check analysis. In spite of these inconsistencies, however, there can be no doubt of the above conclusions after studying the analyses for the first six runs.

During the 135-volt run with sulphate water, lights appeared between the plates in the treater due to ignition of the hydrogen liberated at the cathode. There was a decrease of about 25 per cent in the impurities after passing through the treater. This decrease was obtained, however, with an electrical energy consumption of about 120 kw-hr. per 1000 gal. of water treated. At two cents per kilowatt hour, the cost of this electrical energy would be $2.40 per 1000 gal. treated as compared with 0.4 cent per 1000 gal. for 0.15 lb. of lime to give the same result. This cost, of course, is excessive for 25 per cent purification, and in addition the duriron plates would be eaten away very rapidly with such a high electric current. A greater purification might have been obtained by decreasing the rate of flow of water through the treater, but this would have still further increased the energy consumption per 1000 gal. treated. Decreased rates of flow were tried during the succeeding series of runs in which a carbonate water was used.

Runs 8 to 19 were made with a synthetic carbonate water of similar composition to that used by Neeley at Hartford, Illinois. In runs 8 to 12 inclusive, the alkalinity was reduced from 207 to about 85 parts per million, but this reduction took

place entirely in the feedwater heater, the water analyses before and after the treater being practically the same. In Neeley's apparatus at Hartford, Illinois, the heating and treating took place in the same piece of apparatus so that the separate effects were not so apparent as in the experimental apparatus.

TABLE II.—PRINCIPAL DATA FOR EXPERIMENTAL NEE-WAT SYSTEM

| Type of water | Sulphate | | | | | | | Carbonate | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| Water treated per hr., lb. | 18.4 | 17.6 | 17.6 | 18.6 | 17.7 | 18.0 | 17.5 | 18.2 | 18.2 | 19.2 | 18.0 | 18.1 | 18.0 | 16.5 | 9.0 | 9.3 | 9.3 | 4.8 | 5.4 |
| E.m.f., volts | 25.7 | 49.8 | 50.6 | 50.1 | 49.7 | 98.5 | 133.8 | 25.8 | 49.3 | 74.9 | 99.9 | 49.4 | 50.0 | 140.6 | 139.5 | 101.6 | 49.1 | 49.3 | 99.5 |
| Current, amperes | 0.287 | 0.358 | 0.381 | 0.390 | 0.384 | 0.932 | 1.880 | 0.106 | 0.223 | 0.392 | 0.608 | 0.304 | 0.087 | 0.253 | 0.276 | 0.396 | 0.206 | 0.182 | 0.400 |
| Energy per lb. water, watt-hr. | 0.401 | 1.014 | 1.095 | 1.050 | 1.078 | 5.097 | 14.37 | 0.150 | 0.604 | 1.530 | 3.374 | 0.830 | 0.241 | 2.153 | 4.281 | 4.326 | 2.194 | 1.870 | 7.38 |
| Temperature entering, fahr. | 326 | 325 | 326 | 326 | 325 | 326 | 324 | 323 | 324 | 321 | 318 | 322 | 55 | 52 | 55 | 305 | 310 | 241 | 297 |
| Temperature leaving, fahr. | 248 | 218 | 233 | 237 | 238 | 242 | 271 | 235 | 236 | 233 | 237 | 234 | 57 | 59 | 69 | 183 | 178 | 128 | 161 |
| Alkalinity as $HCO_3$, p.p.m. | | | | | | | | | | | | | | | | | | | |
| Before heater | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 207 | 207 | 207 | 207 | 207 | 207 | 207 | 207 | 207 | 207 | 207 | 207 |
| Before treater | 36 | 30 | 30 | 24 | 24 | 30 | 24 | 85 | 97 | 85 | 85 | 98 | 207 | 201 | 204 | 73 | 85 | 85 | 79 |
| After treater | 24 | 24 | 36 | 30 | 30 | 30 | 18 | 85 | 85 | 85 | 61 | 85 | 207 | 201 | 204 | 61 | 73 | 85 | 49 |
| Calcium, p.p.m. | | | | | | | | | | | | | | | | | | | |
| Before heater | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 |
| Before treater | 34 | 33 | 34 | 32 | 32 | 38 | 38 | 19 | 18 | 21 | 18 | 15 | 50 | 51 | .. | 13 | 18 | .. | 14 |
| After treater | 44 | 37 | 38 | 32 | 32 | 29 | 27 | 17 | 17 | 16 | 11 | 14 | 50 | 50 | .. | 12 | 12 | .. | 9 |
| Magnesium, p.p.m. | | | | | | | | | | | | | | | | | | | |
| Before heater | 7.3 | 7.3 | 7.3 | 7.3 | 7.3 | 7.3 | 7.3 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| Before treater | 8.3 | 10.3 | 6.6 | 8.2 | 7.1 | 6.3 | 10.1 | 13 | 15 | 14 | 14 | 13 | 16 | 16 | .. | 12 | 14 | .. | 12 |
| After treater | 7.8 | 6.2 | 6.9 | 8.4 | 6.0 | 10.5 | 7.4 | 13 | 12 | 13 | 9 | 11 | 16 | 18 | .. | 9 | 12 | .. | 8 |
| Sulphate, p.p.m. | | | | | | | | | | | | | | | | | | | |
| Before heater | 105 | 105 | 105 | 105 | 105 | 105 | 105 | | | | | | | | | | | | |
| Before treater | 120 | 94 | 108 | ... | ... | 120 | 119 | | | | | | | | | | | | |
| After treater | 125 | 155 | 114 | ... | ... | 121 | 104 | | | | | | | | | | | | |

In runs 13, 14 and 15, the heater was not in operation; and in run 15, the rate of water flow was reduced one-half from that used by Neeley. In all three of these runs, no purification took place.

With this reduced rate of flow and hot feedwater, a small amount of purification was accomplished in the treater, as indicated in runs 16 and 17 with 100 and 50 volts respectively. In both of these runs, the treater reduced the alkalinity 12 parts per million while the feedwater heater reduced it 125 parts per million. The rate of flow was then reduced one-half again and runs 18 and 19 made at 50 and 100 volts respectively. In the 50-volt run, no reduction in alkalinity was found in the treater; but in the 100-volt run, the reduction in the treater was 30 parts per million with an energy consumption of 62 kw-hr. per 1000 gal. This reduction of about 30 per cent in impurities would cost $1.24 per 1000 gallons with electrical energy at two cents per kilowatt-hour as compared with 0.3 cent per 1000 gal. for 0.11 lb. of lime to produce the same effect.

The results of this test indicate that only a partial purification of feedwater can be obtained by passing a direct current through it, and that the electrical energy consumption will be excessive for the effect produced. When a direct current is passed through water, hydrogen gas is liberated at the cathode and oxygen gas at the anode. Even though a chamber be provided to collect these gases, a portion will remain in the feedwater and enter the boiler. This, of course, is an undesirable feature of such a process.

No experiments were attempted upon Neeley's "internal system."

### *Kirkaldy System*

In the Kirkaldy system for preventing scale and corrosion in steam boilers, the positive terminal of a direct current circuit is connected to an insulated electrode immersed in the boiler water and the negative terminal is connected to the boiler shell. The electrode is in the form of iron bars and is distributed throughout the boiler in order to bring all of the heating surface within the range of electrolytic action. The minimum distance between the electrode and the boiler tubes or plates is four inches, while the maximum distance depends upon the design of the boiler. A fire-tube boiler is more readily adapted to a correct distribution of the positive electrode than a water-tube boiler. A current equal to one ampere for each 25 boiler hp. is passed through the circuit.

The Kirkaldy system, as covered in the various patents listed as granted to A. Kirkaldy, is an outgrowth of the Cumberland system as covered in the patents granted to P. E. G. Cumberland. The following three British patents to Cumberland may also be referred to, namely, 8,068, May 13, 1909; 19,637, June 27, 1911; 4,251, June 13, 1912. Mr. Alexander Kirkaldy became familiar with the Cumberland system while chief engineer of one of the trans-Atlantic lines, and his patents cover improved insulated supports for the electrodes in order to render his system more effective and reliable than the Cumberland system.

In October, 1927, an inspection was made of an installation of this system in four 250 hp. Scotch marine boilers at the plant of Thomas Oakes and Company, Bloomfield, N. J. The Kirkaldy system had been installed in May and June of that year, at which time there was from three-sixteenths to one-fourth inch of scale on the tubes. At the time of the inspection, the system appeared to be preventing new scale and loosening scale previously deposited. Thus, in one of the boilers examined, the scale was found to be breaking off in pieces up to six or eight inches long and also seemed to be disintegrating. The tubes near the electrodes were fairly clean, while those further away still contained three-sixteenths to one-fourth inch of scale. In a recent letter from this company, however, it has been learned that the system was discontinued after nine months of almost continual repairs and replacements, because the system failed to successfully combat the scale trouble.

Two other installations of the Kirkaldy system

were investigated by letter, namely, at the Delaware station of the Philadelphia Electric Company on feedwater heaters and at the Long Beach plant of the Southern California Edison Company on steam condensers. The Kirkaldy system was said to have materially reduced the pitting and corrosion of the feedwater heaters but considerable trouble was experienced with cracking of the insulators. No difficulty had been experienced with pitting on the condensers. The Kirkaldy system was said to have installed for two and one-half years, but it was impossible to determine how much of this could be credited to the Kirkaldy system.

### *Hauptvogel's System*

In the Hauptvogel system of scale and corrosion prevention, a small direct current is passed through the metal of the boiler. The method employed of arranging electrical circuits to obtain the low voltage required, is covered in U. S. Patent No. 1,726,-738. The average working conditions are 0.1 to 0.5 volts and 0.5 to 1.5 amperes. As no installations had been made in this country in 1927, the only information available was that in British Patent No. 233,657, issued July 9, 1925, to Fredrick Hauptvogel. and an article in Wochenschrift Fuer Brauerei, Nov. 7, 1925, by Dipl. Eng. Gesell., Chief of Research Department, Fermentations Trades Institution, Berlin.

The conclusions reached in the above mentioned article are:

"From the above test under actual working conditions the Process may be valued as follows: that it does not absolutely prevent the formation of scale and incrustation but that it considerably decreases the deposit of hard scale and makes the remainder of such a loose nature that it breaks off easily and without fear of harmful secondary actions. Although the total costs for the various cleaning processes are not entirely eliminated, a saving has been made and the period for working the boiler has been increased from 3 months to 4-5 months." The tests referred to in this quotation were only general statements as to the conditions of several boilers after certain periods of operation. No water and scale analyses nor quantities of water fed to the boilers, etc., were given.

### *Agfil System*

In its original form, the Agfil system consisted of a thermocouple clamped to the steam header with the negative lead connected to the blow-off nozzle and the positive lead attached to several remote points of the boiler as described in U. S. Patent No. 1,558,646. Thus, a very small direct current was passed through the metal of the boiler. Through an accidental loose connection which swung back and forth against the boiler, it was said that a pulsating current was found much more effective than a steady current. Consequently, a second patent was obtained, U. S. Patent No. 1,558,-647, covering the application of a pulsating current and the design of a vibrator to produce the pulsations automatically. The vibrator proved unreliable and was replaced by a motor-driven interrupter with metal contacts producing about 7000 pulsations per minute. A sufficient number of thermocouples are placed in parallel to give an electric current of about 50 milliamperes per 100 boiler hp. In the latest installations in 1928, a small condenser was connected as a shunt around the interrupter and it was claimed that oscillations of radio frequency were set up, which assisted materially in preventing scale.

The condenser in parallel with the interrupter modifies the form of the current wave but does not increase the frequency of 7000 pulsations per min. as determined by the speed of the motor-driven interrupter. As radio frequencies vary from 10,000 to 5,000,000 cycles per sec., it is seen that such frequencies are not quite reached.

It was claimed that the Agfil system had been very successful in Europe, particularly on the Danube River steamboats. In the United States it had met with varying degrees of success. It was said that in some plants the Agfil system had entirely eliminated scale but that in other plants it had been ineffective or had reduced but not eliminated the scale.

TABLE III.—ANALYSES OF DEPOSITS FROM EXPERIMENTAL NEE-WAT SYSTEM

AFTER OPERATING WITH SULPHATE WATER

Samples Taken after Run No. 5

| | Positive Electrode | Negative Electrode | Filter | Feedwater Heater |
|---|---|---|---|---|
| $SiO_2$, per cent | 36.5 | 18.0 | 65.1 | 5.0 |
| $Fe_2O_3$ and $Al_2O_3$, per cent | 28.4 | 16.4 | 11.2 | 65.0 |
| CaO, per cent | 9.4 | 12.0 | 0.0 | 0.0 |
| MgO, per cent | 0.0 | 12.1 | 0.0 | 0.0 |
| $SO_3$, per cent | 0.0 | Trace | 0.0 | 0.0 |
| Loss on ignition, per cent | ... | ... | 18.8 | ... |
| $CO_2$, $H_2O$ and unaccounted for, per cent | 25.7 | 41.5 | 4.9 | 30.0 |

AFTER OPERATING WITH CARBONATE WATER

Samples Taken after Run No. 12

| | Positive Electrode | Negative Electrode | Filter |
|---|---|---|---|
| $SiO_2$, $Fe_2O_3$ and $Al_2O_3$, per cent | 61.0 | 38.9 | 95.2 |
| CaO, per cent | 8.0 | 17.5 | Trace |
| MgO, per cent | 4.2 | 6.6 | Trace |
| $CO_2$, $H_2O$ and unaccounted for, per cent | 26.8 | 37.0 | 4.8 |

An installation of the Agfil system was inspected in 1928 at the plant of the L. A. Dreyfus Company, Staten Island, New York. This plant contained four 160 hp. return tubular boilers and one 250 hp. Springfield water-tube boiler, all equipped with the Agfil system. Three Agfil units were installed, one unit for the Springfield boiler and one unit for each pair of return tubular boilers. The negative lead of the thermopile for the return tubular boilers was connected through the interrupter to the blow-off nozzles of two boilers. The positive lead had four branches, two being connected to the front head of each of the pair of boilers. The negative lead of the thermopile for the Springfield boiler was connected to the blow-off pipe and the positive lead was connected to each of the front headers. To test the operation of the system, a milliammeter was mounted on the panel board which supported the interrupter. The milliammeter could be connected into the various circuits by means of small knife switches also mounted on the panel board.

The operating engineer was very much pleased with the Agfil system. During the four years it had been in operation, no trouble had been experienced from scale, while before that time they had had very hard scale. Before installing the Agfil system, several boiler compounds had been tried without success. Scale would build up to about ¼ inch in a year's time and would have to be knocked off. After installing the Agfil system, the scale gradually broke off in large slabs and has never reappeared. The impurities in the water settled out as a sludge instead of sticking to the heating surface and could be eliminated through the blow-off. For this purpose, the boilers were blown down about 2 inches twice daily. The boilers were washed out about three times per year but no further cleaning was required.

One of the return tubular boilers was open and the heating surface was inspected. At no point was the scale thicker than 1/32 inch while in many places the tubes were practically clean. There was a slight amount of pitting, but the operating engineer claimed that this was due to oil and had been experienced before the installation of the Agfil system as well as after its installation. The feedwater was about 50 per cent distilled water from process heating coils and 50 per cent make-up from the New York City water system. New York City water is very soft, but will produce scale if its use is continued for a sufficient length of time.

In a recent letter from the L. A. Dreyfus Company, it is stated "that the Springfield boiler has been in continuous service for about 5½ years at 140 per cent to 150 per cent of rating. The four 160 hp. boilers have only been in intermittent service during this time. The Agfil system was installed on the Springfield boiler when new and there are no signs of pitting in either the tubes or drums. Twice a year the tubes are cleaned with a water turbine under 50 pounds pressure. A turbine hammer has never been used on the boiler. Also twice a year the steam drum is wiped out with a cloth. This is all that is necessary to remove the slight deposit of scale every six months. Twelve to fifteen pounds a week of a common alkali are injected with the feedwater to emulsify the oil coming back with the returns. We consider that the Agfil system when given ordinary care is exceptionally efficient in keeping down boiler scale."

The plant of the Bellman Brook Bleachery was also visited to inspect an Agfil system installed on two 500 hp. Springfield water-tube boilers. The operating engineer stated that considerable trouble had been experienced from scale before the system was installed, but that since its installation no scale had formed. Both boilers were in operation at the time of the visit and had been on the line for over a year without cleaning. The last time the boilers had been opened there was no scale. The plant required about 50 per cent make-up. Before the Agfil system was installed, the make-up was obtained from a nearby stream; but some time later, a water softening system was installed and the make-up then consisted of softened water containing only 1.2 grain per gallon of hardness.

In a recent letter from the Bellman Brook Bleachery Company, it was stated that suddenly, after a period of about three years, scale formations started to gather and on the next semi-annual internal inspection, a number of tubes were found closed up solid. An analysis of the water supply disclosed that a considerable quantity of chemicals was being added to the water supply from some outside source. After subsequent tests, the Agfil system was concluded to be inadequate and was discontinued, chemical treatment being resorted to.

### *Conclusions*

It is believed that there may be some merit in electrical methods of preventing scale and corrosion in steam boilers, but that such methods may not prevent scale and corrosion in all cases. In some cases, local corrosion and pitting might be accentuated. In any such application, the complicated arrangement of tubes, drums, etc., in a modern steam boiler, makes it practically impossible to obtain a uniform effect of the impressed electrical current throughout the whole structure. Considerable experimental research will probably be required to determine definitely the best electrical system to employ and the conditions under which scale and corrosion can be prevented; also, whether electrical methods have any advantages over chemical methods or whether both methods should be used together.

PARTIAL LIST OF UNITED STATES PATENTS PERTAINING TO ELECTRICAL METHODS PROPOSED FOR PREVENTING SCALE AND CORROSION IN STEAM BOILERS AND FOR PURIFYING WATER.

| Patent No. | Date of Issue | Patentee |
|---|---|---|
| 22,271 | Dec. 7, 1858 | R. L. Lloyd |
| 50,774 | Oct. 31, 1865 | A. F. Porter |
| 59,768 | Nov. 20, 1866 | A. T. Hay |
| 59,910 | Nov. 20, 1866 | A. T. Hay |
| 62,093 | Feb. 12, 1867 | P. H. Vander Weyde |
| 88,285 | Mar. 30, 1869 | M. G. Farmer |
| 140,196 | June 24, 1873 | A. T. Hay |
| 392,736 | Nov. 13, 1888 | M. Kotyra |
| 669,922 | Mar. 12, 1901 | J. Gottlob |
| 921,641 | May 11, 1909 | P. E. G. Cumberland |
| 948,968 | Feb. 8, 1910 | P. E. G. Cumberland |
| 999,108 | July 25, 1911 | A. S. Hickey |
| 1,003,604 | Sept. 19, 1911 | A. B. Herrick |
| 1,020,480 | Mar. 19, 1912 | P. E. G. Cumberland |
| 1,055,327 | Mar. 11, 1913 | C. Hering |
| 1,080,826 | Dec. 9, 1913 | G. H. Gibson |
| 1,308,040 | July 1, 1919 | L. W. Chubb |
| 1,449,991 | Mar. 27, 1923 | L. O. Gunderson |
| 1,506,306 | Aug. 26, 1924 | A. Kirkaldy |
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| 1,558,646 | Oct. 27, 1925 | W. Thalhofer |
| 1,558,647 | Oct. 27, 1925 | W. Thalhofer |
| 1,568,714 | Jan. 5, 1926 | C. E. Bonine |
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| 1,611,853 | Dec. 21, 1926 | H. J. Creighton |
| 1,639,457 | Aug. 16, 1927 | A. Kirkaldy |
| 1,699,974 | Jan. 22, 1929 | A. Kirkaldy |
| 1,726,738 | Sept. 3, 1929 | F. Hauptvogel |
| 1,736,986 | Nov. 26, 1929 | W. Thalhofer |
| 1,736,987 | Nov. 26, 1929 | W. Thalhofer |
| 1,773,274 | Aug. 19, 1930 | G. S. Neeley |
| 1,773,275 | Aug. 19, 1930 | G. S. Neeley |
| 1,788,485 | Jan. 13, 1931 | L. O. Gunderson |
| 1,796,715 | Mar. 17, 1931 | A. Kirkaldy |
| 1,816,487 | July 28, 1931 | A. Kirkaldy |
| 1,825,477 | Sept. 29, 1931 | W. M. Reichart |
| 1,831,075 | Nov. 10, 1931 | G. S. Neeley |
| 1,831,076 | Nov. 10, 1931 | G. S. Neeley |
| 1,842,541 | Jan. 26, 1932 | E. Cumberland |
| 1,843,673 | Feb. 2, 1932 | G. S. Hesenbruch |

# Patents

By GEORGE RAMSEY

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**All engineers should have some knowledge of the nature of patents and the more important aspects of patent law. In this article, which is virtually the complete text of a paper presented before the Metropolitan Section, Student Branch, of the A. S. M. E., New York, March 9, 1932, the author first reviews the early history of patent law, in order to show the origin and evolution of the principles involved. He next describes present-day patent office procedure and then discusses the subject of patents broadly with respect to employer and employee, joint ownership and litigation. The concluding part of the article discusses the importance of patents in industry . . . Anyone desiring more detailed information, especially with respect to procedure, can obtain it by writing to the U. S. Department of Commerce, Patent Office, Washington, D. C., for a copy of "Rules of Practice in the U. S. Patent Office."**

*English History*

PATENTS are really personal property and the laws governing patents are a specialized branch of personal property law.

We will go back to the history of the patent system to get a comprehensive knowledge of what it is all about. The majority of our fundamental laws in the United States find precedent in the laws or customs of England and this is true with the patent laws.

Some few hundred years ago, the Kings and rulers of England had great powers by the way of prerogatives, which were powers or authority recognized at that time as being inherent in the Sovereign. Taxes were unpopular and the collection of taxes directed the wrath of the people against the Government. Some of the Sovereigns, particularly Queen Elizabeth, discovered a means of raising taxes by the granting of monopolies to favored individuals by the way of "letters patents" on the basis that the Crown should share in the profits from the monopolies. (A monopoly may be defined as an exclusive privilege which takes away an established right.) These monopolistic patents were grants to individuals giving them the exclusive rights to manufacture, import, and sell, some article within a prescribed territory; and providing penalties, such as seizure and destruction of the goods and arrest of the offender who violated these patent grants. Patents of exclusive rights were granted by Queen Elizabeth which covered many necessities of life, for example, to sell salt, vinegar, starch, oils, paper, etc., to make boots and shoes, to collect ashes for the City of London, and many others. A monopolistic patent is one of the first of which we have a Court record. The Court decided that this patent was against the common law prohibiting monopolies, and, therefore, held the patent unenforceable. The basis for the decision was that the business of making playing cards had been established in England before the grant of this patent.

There was no way under the English law whereby an inventor could retain any especial benefit from his invention except to try to keep the invention secret. This might be satisfactory for chemical processes, but not for mechanical devices which carry in themselves the evidence of their novelty. Inventors, therefore, sought the assistance of courtiers and others who could reach the Crown to make a deal to obtain patents for limited times giving them exclusive rights in their inventions, and in turn agreed that the Crown should share in the profits. The first of this type of patent appears to have reached the English Courts about 1691. The meager report does not tell us to what the invention related, but it does convey the important fact that this type patent based on a new invention was held not to be a monopoly and was held to be a proper grant which would encourage industry in the realm, and, therefore, the grant was sustained.

You will observe that when one of these monopolistic patents in England got to the Courts, it was usually stricken down but this did not stop the Crown from continuing to grant monopolistic pat-

ents which harrassed the public. This was an easier way than by taxes to raise money for the Crown and the wrath of the public was directed against the patentee who attempted to enforce his monopoly and not against the Crown which had granted the monopoly. The condition became so bad that Parliament threatened to take away the prerogatives of the Crown. This was a serious matter and meant much to the Sovereign. Queen Elizabeth, therefore, made a personal appearance before Parliament, one of the last that she ever made. She personally addressed Parliament on this subject and pointed out that she had never touched pen to paper to grant a patent except that it had been represented to her that the grant of such patents should be for the benefit of the public at large although incidentally perhaps of private profit to some well deserving friend or courtier. She was also defended before Parliament by Robert Bacon. Moreover, at this time, Queen Elizabeth revoked many of the most obnoxious monopolistic patents. Parliament, for the time being, had its temper appeased, but the storm arose again and under James I in 1623, Parliament passed what is known as the Statute of Monopolies in which it took away from the Crown the prerogative of granting monopolies, except that the Crown might grant letters patents for inventions new in the realm or inventions which were unknown in the realm but which were brought into the realm from over the seas, and that the life of these patents should be limited to a period of fourteen years. It is because of this exception in the Statute of Monopolies that patents on inventions may be granted in England. It is also because of their basis being in the Statute of Monopolies that patents on inventions are sometimes referred to as being monopolistic in character. You will observe, however, that the definition of a monopoly, namely, the taking away from the public of some right or privilege existing in the public, does not truly fit a patent on a new invention, because if the invention is new and novel, the public never had any rights under such new and novel subject-matter. Patents on inventions however, do restrict the natural right to make use of improvements and in that sense patents on inventions are monopolistic. In Queen Anne's reign (1702-1714), a statute was passed requiring patents to have written specification as a safeguard against fraud. You will observe that the English patent rests on one of the prerogatives left to the Crown, that is, it is a property right created by the Crown. In fact it is in reality a bargain with the King to give the invention to the public at the end of fourteen years in exchange for exclusive rights for the period of fourteen years. English patents are in effect contracts with the government.

*United States History*

We leave the shores of England and come to America, and we find the Colonies brought with them the English laws and customs somewhat broadened to suit the new environment, and we find that several of the early Colonies or States, in a few instances, granted patents.

When the Constitutional Convention met at Philadelphia and began drafting the Constitution, there were three drafts, a first draft, a second draft, and a revision of the second which comprised the Constitution as adopted. In the first draft, there was no mention whatever of patents or copyrights. James Madison of Virginia and Charles Pickney of South Carolina both suggested clauses to go into the second draft of the Constitution pertaining to this subject-matter. Madison suggested that Congress have power to encourage the advancement of useful knowledge and discoveries. Pickney, who was more concise, suggested that Congress have the power to grant patents for useful inventions. These two resolutions were referred to a committee known as the Committee of Detail comprising one delegate from each State. There were eleven States represented at the Convention at this time and the Committee of Detail of eleven reported a resolution recommending a clause to the Constitution in the wording of the Constitutional clause substantially as it stands today and which is to be found in Article 1, section 8, namely:

> "Congress shall have power to promote the progress of science and useful arts by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries."

The resolution as originally submitted was the same with the exception that it specified "a limited time." This was changed to make it "limited times," thereby placing it in the power of Congress to extend patents from time to time if it so saw fit.

This clause in the Constitution marks an epic in the viewpoint of the world as to the rights of an individual as to inventions. You will observe that this clause of the Constitution is the section relating to the powers of Congress, which is the legislative body that passes laws protecting property rights. You will note in England that the right to a patent emanated from the Crown, based on the prerogatives of the Sovereign, which actually created the right that the subject of himself did possess under the English law. When we come to the United States, we find the citizen proclaiming himself as having certain inherent inalienable rights as set forth in the Declaration of Independence. This same thought is carried forward in the Constitution, particularly as to patents, because here we find our fundamental statutory document specifying that Congress shall have power to "secure" to authors and inventors; recognizing the right being inherent in the authors and inventors but that the right is very insecure. Their only course of security without this protecting law would be to maintain their inventions as secret processes which we have seen was not satisfactory.

George Washington in his first message to Congress called attention to the necessity of encouraging manufacturers of new inventions in the United States. The first session of Congress did not act upon this suggestion, but in the second session, the first patent law of 1790 was passed. This patent law made the granting of a patent a solemn act in

that the grants were signed by the President of the United States, the Secretary of State and the Secretary of War. The Act of 1790 contained many fundamental elements that we are working under today. In 1793, it was decided that patents should be made more easy to obtain and a type of registration system was inaugurated. This did not work out so well. Under the law of 1790, the patent was prima facie evidence that the patentee was the first inventor of the thing specified. Under the law of 1793, the patent was not prima facie evidence but when the patentee got into Court, it was necessary for the patentee to establish the novelty of his invention. The patents under the Acts of 1790 and 1793, copying the English law, had a life of fourteen years. At later dates other acts relating to details were passed, more especially an act permitting a patent to be extended for seven years. Under the Act of 1793, petitions for patents were addressed to the Secretary of State, and were delivered to the Attorney General for examination, and if found to be in proper form patents were granted thereon. The patents, however, were issued through the State Department. The next real milestone is the Act of 1836 which established the Patent Office under the Department of State. It provided for an examination as to novelty, thus establishing the examining corps and the patent law system substantially the same as it is today. The Patent Office was transferred from the Department of State to the Department of Interior and then finally to the Department of Commerce. In this Act of 1836, it was provided that the patents should be for a period of seventeen years, and without any extensions. An interesting side light in this act is that citizens of the United States were required to pay $30.; aliens who made oath of their intention of becoming a citizen and had been residents of the United States for a year paid the same, but if the applicant was a subject of the King of Great Britain, he was stuck $500.00. The fees have been changed from time to time and now are $25.00 when the application is filed and $25.00 when the application is allowed plus $1.00 for each claim above twenty. With this substantive Act of 1836, we may come down to date.

### *Patent Office Procedure*

An application for patent should be prepared by one skilled in the Patent Laws because of the extreme technicalities surrounding the soliciting of patents and also the enforcement of patents in the Courts. The application should be drawn to meet the ultimate test in Court, therefore, the man who drafts a patent application should know something of what happens when a patent gets into litigation. This very important step in the creation of a patent is often not given sufficient serious consideration to the sorrow of the client when the patent gets into the Courts. When the application is prepared, drawings of a specified size are made; a description or specification of the machine as shown in the drawings is made; and then at the end of the description are certain numbered paragraphs referred to as "claims." These are the heart of the patent and comprise a survey of the invention set out in the technical language of patent law. The claims define the invention in its various aspects, so that it is not unusual to find a large number of claims attached to one specification. Before the Act of 1836, claims were not required, but as early as 1820, it became the custom of patent solicitors to point out at the end of the specification what they considered as the novel features of the invention. Before that time, the invention was merely described and shown in drawings and sometimes in a model. Then it was up to the Court to figure out what was new and how broadly the patent could be interpreted. The claim system, however, defines the scope of the patent and because of this definition of scope when a patent is litigated, the claims are subjected to the most severe scrutiny and must stand the brunt of the opponent's attacks.

The application must be executed by the inventor. When the application is filed in the Patent Office, it receives a serial number and a filing date, and is sent to the particular division of the Patent Office which handles the applications on the invention defined therein. It is reached for examination in chronological order by the Examiner on whose desk it is deposited. He reads the specification, examreads the claims with all prior art patents and publications bearing on the subject in mind. If ines the drawings for errors and defects, and then he does not know of a prior art patent that defines the invention set forth in a claim, he makes a search through files of both United States and foreign prior art patents to refresh his memory and to see if he can find a reference for the claim. If the claim is in proper form and from a legal standpoint is technically correct and the Examiner is unable to find any prior art patent or publication which responds to the claim, he indicates the claim as allowable. The Examiner rejects those claims, which, in his opinion, are neither in correct form nor define a new invention in the known prior art. He writes a letter setting forth his conclusions to the attorney in the case. The attorney orders from the Patent Office copies of the patents cited by the Examiner. Domestic patents may be obtained at the cost of ten cents each, but as to foreign patents and publications it is necessary to obtain photostats. The attorney studies the rejected claims and the prior art to see if he can discover how the claims may be amended or changed to avoid the prior art and so become allowed. A response must be made to a Patent Office action within six months from the date thereof, otherwise the application under the law is abandoned. The procedure of amendments and rejections are both technical and complicated and many things may happen. However, this process of rejection and amendment goes on until the case is closed. If the case is allowed and the final fee is paid, it becomes a patent. If the application is finally rejected by the Examiner the law permits appeals to be taken. If the Examiner is reversed, the patent may issue, but if the Examiner is finally sustained, the patent is refused.

If two or more applicants file applications for the same broad invention, even though in different forms, the Patent Office declares an interference. Interference proceedings are very complicated but are intended to determine which is the first and original inventor. When this has been finally determined an award of priority is made to the successful party and a patent issues to him. The finding of this ultimate fact may take several years in a hard fought interference. Interferences, legally, are perhaps the most technical branch of Patent Law.

Applications for patents, and patents are assignable in whole or in part, and a record division is provided in the Patent Office to provide for recording such assignments. Assignments for granted patents should be recorded because if not recorded within ninety days, an innocent purchaser without notice will take good title as against one who has neglected to record his assignment.

When the patent is granted, it gives the right to *exclude* others from making, selling or using the patented invention in the United States and territories for a period of seventeen years from the date of the grant. When the patent expires, the public is then free to use the patented invention. A patent does not convey the right to the patentee to "use" his own invention because this right belongs to the public by common law, but it may be taken away by statute law, and in this case, may be taken away by some prior, broader patent. For example, when Bell invented the telephone, he discovered a broadly new field of communication and he obtained a very broad patent, the claims of which substantially cover a method and apparatus for translating sound waves into electric waves and then reproducing sound from the electric waves. These claims were sufficiently broad to cover any type of telephone. Therefore, such claims are known as basic claims. Every telephone improvement made while the Bell telephone patent was alive infringed these broad claims, and, therefore, while others improved the Bell basic invention, they were not entitled to use their improvements until the basic Bell patent expired. The same is true of the sewing machine. Howe invented the needle with the eye in the point of the needle and a later inventor invented the grooves in the side of the needle which hold the thread when sewing through heavy substances, thereby preventing cutting of the thread by the side walls of the hole comprising the eye. Howe did not invent the grooved needle, and, therefore, was not entitled to use this needle. The second inventor did not invent the broad idea of a needle with the eye thereof in the point, and, therefore, he could not use Howe's invention. The result was that the two got together, and we have the practical sewing machine needle of today.

Where a patentee sells directly to the public, even though he uses agents he may fix the price of his patented article as to the initial sale. He cannot fix the price if he sells through jobbers who purchase the article, and price fixing cannot go beyond the first sale to the buying public.

### *Employer and Employee*

It is a principle of law that an invention and a patent thereon belongs to the inventor in the absence of contract. Therefore, if you are in charge of the design of a machine and have several designers under your direction and one of these men makes an invention in connection with that machine, if you did not employ him for the specific job of making that invention, but if you employed him generally for designing machinery, then any patent which he may obtain upon his invention is his own. However, if he permitted you to use the invention in a machine without objection or any payment of royalty, you have a "shop right," that is, a right to continue to make such machines without paying royalty in that particular shop. A "shop right" is a limited license. If your shop is located in Albany, and your company has a branch in Chicago, you have no right to practice this same invention in Chicago. Also if you should desire to sell your shop in Albany, you cannot sell the "shop right" since it is a personal and non-transferable license. The inventor, on the other hand, has obtained his patent with only your shop right outstanding. He can make his patented article or he may license anyone he sees fit to make the patented device. He can sell his patent to a competitor. Of course, this competitor cannot take away your shop right but on the other hand, you have no redress against what the competitor may do with the invention, other than not to disturb your shop right. Therefore, if you are in the manufacturing business employing skilled artisans to improve your product or make new inventions, it is only fair that you should pay these artisans a sufficient amount to justify their turning over to you any inventions which they may make in connection with your business. Contracts of this kind, when properly drawn, are invariably sustained by the Courts. It is entirely fair to include in such contract that any invention in your line which the employee may make within a period of one or two years or a reasonable time after the employee leaves your company, shall likewise belong to your company.

### *Owners of an Undivided Part of a Patent*

Another feature of patent law that is not well known is the status of the owner of an undivided fractional part of a patent. Sometimes two or more persons collaborate to make an invention, one making this suggestion and the other making that suggestion. Under these conditions, they are joint inventors and all of them should sign the application for patent because the law requires the application shall be executed by "the inventor." "The inventor," in this case, is a plurality of persons rather than one, but if only one executes the papers "the inventor" is not before the Patent Office, and the applicant has not complied with the laws and the patent is invalid. If, on the other hand, there is some question as to whether all of these parties

are true joint inventors, it is best to have all sign or execute the papers because in that case "the inventor" is before the Patent Office and the other parties are excess baggage. The patent as a rule will not be stricken down in the latter case where it will be in the former case.

Where an invention is completely worked out in the mind of the inventor but wherein he may lack skill to embody the invention in a mechanical device or he may seek information as to a particular well known reaction of chemicals or as to the particular kind of known electric circuit, which will produce the result which he has outlined and designed, in this case, the artisans on whom he calls for information do not become joint inventors with the true inventor. They have merely supplied the skill of the art and skill of the art is not invention. The invention was made by the man with the original concept.

Where several parties are joint owners of a fractional part of a patent, either as joint inventors or as assignees of a part, any one of these parties may sell, license manufacture, in fact, do anything he pleases with his fractional part without in any way accounting to the other owners, in the absence of a contract not to act without their consent. In other words, one owner of a part of the patent may make one million dollars while his associates have not been able to make a cent, but the associates (in the absence of a specific contract) cannot get one cent of that million.

*Patent Litigation*

In the case of infringement of the patent, the patentee is entitled to recover both profits and damages for the infringing act. As to articles which have been manufactured and sold before the patent was granted and while it was pending as an application, no redress is obtainable unless the article patented is in the nature of a large machine such as a printing press, a locomotive or something of that type which continues in *use* after the grant of the patent. In that case, the patentee may sue to stop the "use" of the device, but can obtain neither profits nor damages for manufacture or sales made before the grant of the patent.

Infringement of patents is what is known in the law as a tort. A tort may briefly be defined as a private or civil wrong or injury, for example, if a man destroys your lawn by walking over it, if he trespasses on your property, or says something to injure your reputation, he commits a tort; so if he infringes your patent, this is a civil wrong, a tort, and you bring suit by filing a Bill of Complaint in the Federal Courts which by law have exclusive jurisdiction of patent law suits, asking for an injunction and for an accounting as to profits and damages. The defendant may defend by saying in his answer that he does not infringe or that your patent is invalid for many reasons; for example, that you are not the first inventor, that the invention had been in public use more than two years before you applied for a patent, or that it was disclosed in a patent or described in a publication more than two years before you applied for a patent, or that the machine or device disclosed in your patent is inoperative, or any other of the twenty some defenses that may be raised. Trials for infringement are usually in Equity before a United States District Judge, without a jury. The plaintiff puts on witnesses to show that the defendant's device comes within the scope of the plaintiff's patent. Usually experts are employed for this purpose. Some times, the plaintiff puts on witnesses to show the extent of the business which has been built up under the patent. After the plaintiff has made out his prima facie case of infringement, he rests. The defendant then introduces testimony to show the patent is not valid or to show that the defendant's device is different from the plaintiff's patent, and, therefore, does not infringe. If the defendant succeeds, the Bill of Complaint is dismissed and the plaintiff may appeal to the Court of Appeals of the respective Circuit in which the suit is brought. If the defendant sustains his defense in the Court of Appeals, the bill is dismissed and the case is finally closed except the plaintiff may petition the Supreme Court to review the case. Usually, this petition is denied.

There are now ten Circuit Courts of Appeals covering the United States and territories, and it sometimes happens that a patent will be sustained in one Circuit against one defendant and will be held invalid in another Circuit against another defendant. Where this happens, the Supreme Court, upon petition, will usually review the case and decide which of the Circuit Courts was correct in its decision.

If the plaintiff should win, then the case is sent back to the District Court, which Court appoints a Master who is an officer of the Court and powered to hear testimony and reach a conclusion. In other words, he is, in effect, a right arm of the Court to relieve the Court f detail work on points which have been decided by the Court. The Master hears testimony as to net profits which the defendant has made, and as to how much the plaintiff has been damaged by the defendant. When it comes to damages, damages must be proven in a patent case the same as in any other case. In other words, if the plaintiff was making a profit of fifty dollars on a machine, he may show that the defendant was the direct cause why he did not sell a certain machine and make his profit of fifty dollars, and the plaintiff was thereby damaged to that extent; or if he can prove that defendant's coming into the field cut into his price so that he was only able to sell the machine for a profit of ten dollars, whereas before he had a profit of fifty dollars, then also he has proven damage. However, the proof must be direct and not speculative.

You may also find yourself in difficulty as an infringer by selling some element of a patent combination, such as a common-place motor, provided you know that motor is to be used in a patented combination. This is called contributory infringement. A District Court has recently held that electric clocks, which are merely synchronous motors

and gearing, are infringements of a patent which covers a time controlled electrical alternating current to be used with a synchronous motor geared to indicate time, when such motors are sold to be used in such circuit as time pieces. You will note this patent in its specific terms does not cover the clock itself but covers the combination of a source of alternating current, a time control for the current, and a synchronous motor driven in harmony with the timed alternations. However, the motor is a part of that combination and when you knowingly sell something to be used in an exclusive patented invention you have acted to contribute to the infringing result. Therefore, you may be liable.

The principal weapon which is most powerful and is most to be feared in patent cases is the power of injunction. The Courts invariably enjoin, or in other words prohibit, a defendant from making, using, or selling an infringing device. This power is so great that it may close up a factory. Usually, but not always, the plaintiff is willing to grant a license to continue manufacture providing the license fee is satisfactory to enable the plaintiff to make a profit from its invention. A license fee of five cents per article gives a differential of ten cents to the plaintiff providing the plaintiff is manufacturing and selling a competing article. The reason being that the defendant pays out five cents, and, therefore, is out of pocket that much, and since he pays it to plaintiff, plaintiff is in pocket five cents. The consequence is from the net cost to defendant to the profit of plaintiff means a differential of ten cents, so that a royalty is a great advantage to a plaintiff.

*Patents in Industry*

In connection with engineering work, it often becomes desirable to determine if a particular machine or a particular project involves any patented structures. The only way this can be determined is to make a survey of the claims of all unexpired patents, (that is, patents less than seventeen years old) which bear on the particular subject. This sometimes becomes a very sizeable undertaking, particularly in a crowded art like radio where the art has grown up in recent years and has grown very rapidly and broad patents have not yet expired. This is a job which requires the highest skill of a patent lawyer. He must not only be able to determine the question of infringement, that is, he must know whether anyone of thousands of claims in hundreds of patents will cover the device in question, but he must also know how far the Court is likely to consider the claims to be construed as equivalents. An equivalent is that which performs substantially the same function in substantially the same way to secure substantially the same result. In other words, if a weight is replaced by a spring, the weight may constitute an infringement of a claim which calls for a spring. Furthermore, the attorney must be capable of determining if any patent which appears to be infringed is valid. If he decides it is invalid he may recommend that his client go ahead regardless of the apparent infringement. The matter of infringement and validity searches and reports is one in which a great responsibility rests upon the counsellor, because his decision often means the investment of large sums of money in an enterprise. If the advice of the counsellor is wrong, the enterprise may be forced into failure by the successful litigation of some patent which the counsellor either overlooked or felt could not be sustained.

Every patent owned by a manufacturer becomes a door in a protective wall surrounding the enterprise. This door opens outwardly to permit the business to develop, but it closes against efforts of an outsider to break into the protected enterprise. It is therefore advisable for a manufacturer to patent everything in his line whether he expects to manufacture the specific device or not.

The patent system is the bed rock of our industrial growth. Holland had no patent system until recently, thus she has few manufacturers and is almost entirely an agricultural country. Switzerland had no patent system and her representative to the Centennial in Philadelphia in 1876 reported to his government that unless a patent system was inaugurated the United States would lead the world in the watch industry. This happened, and then Switzerland established a patent system.

Inventors are sometimes accused of being dreamers. But when constructive dreams are protected by patents they often become tangible concrete things. Thus the wealth of the country is built up. The dreams of yesterday are the realities of today, often the luxuries, but the luxuries of today become the necessities of tomorrow.

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## Bernard F. Weadock New Head of N. E. L. A.

James F. Owens, President, announces the appointment of Bernard F. Weadock as executive director of the National Electric Light Association to succeed Paul S. Clapp, who resigned recently to become vice president of the Columbia Gas and Electric Corporation.

Mr. Weadock began his career in 1905 in the Corporation Counsel's office of the City of Detroit and later became Assistant Corporation Counsel, in which capacity he remained until 1912. He then became general attorney for the Detroit United Lines and acted as assistant to the president until 1920, when he entered into the general practice of law and in 1924 he came to New York as a member of the law firm of J. C. and B. F. Weadock. In 1928 he severed his connection with that firm to become special counsel for the electrical utilities in connection with the Federal Trade Commission's investigation.

. Mr. Weadock assumed the duties of his new office on April 1. He will continue his present work before the Federal Trade Commission.

# The Design of Steam Generating Plants

## PART II

### The Three Natural Fuels

By F. H. ROSENCRANTS, Consulting Engineer
Combustion Engineering Corporation, New York

**In this article, the second of his series, the author considers the fuel resources of the United States with respect to present and future availability for stationary steam plants. Present supply and future availability of the three principal fuels both have an important bearing on the design of steam plants, a point which is thoroughly discussed, especially in the latter part of the article where the author stresses the importance of not closing the door to the future use of coal because of present conditions favoring the use of other fuels . . . The accompanying tables will be found valuable for reference.**

AN idea of the relative consumption of the three natural fuels, i.e., coal, oil and natural gas, in stationary steam-generating plants of the United States, is conveyed by a study of Table 2. This table applies only to fuels used in connection with the generation of electricity, but it seems reasonable to assume that the relative consumption of the three fuels will be the same for stationary steam plants not included in this category.

Of the three fuels coal is by far the most abundant. It is the most widely distributed and the quality of all known fields is well established.

The map, Fig. 2, and Table 3, give a general idea of the location of coal fields and of the quantities and their general classifications.

Table 4[1] reveals that although the western states dominate in quantity of coal deposits, the eastern states dominate in coal production. It will be observed that the ten states containing the largest quantities of coal account for 83 per cent of the deposits and that the ten largest producing states account for 94 per cent of total production.

The concentration of population and industry in the eastern states and the proximity of their coal fields to the principal ports for supplying marine and export requirements, account in large measure for the preponderance of coal production in this section of the country. An added factor of great influence, however, is the distinctly better quality of the coal. Nine-tenths of the high rank coal lies in the Appalachian region. By high rank is meant those coals which are low in moisture, high in the ratio of fixed carbon to volatile matter and low in ash content. Even in the Appalachian region the coals along the eastern side of the field are of higher rank than those along the western side. Generally speaking, the rank of coal deteriorates progressively as we proceed from the east to the west until we reach the fields of Colorado and Wyoming. In these latter States there are appreciable quantities of bituminous coal which though inferior to the coals of the Appalachian region are superior to the coals of the Iowa, Missouri and Kansas fields. In Table 5 the samples of coal listed are taken progressively from east to west and while so brief a table admits of many exceptions, it gives a general picture of the variation in coal quality insofar as it can be shown by the proximate analysis. It also pretty well covers the quality range of all coals found in the United States[2].

The aggregate production of coal to date in the United States is approximately 0.75 per cent of the present known deposits and no region is at the moment remotely approaching exhaustion. The eastern fields will undoubtedly be exhausted first but even this will not occur for a period of several centuries. It will, therefore, be apparent that a steam plant located at any point may be assured of a supply of coal of the characteristics for which it was designed for a period of time far in excess of the life of the equipment.

Dating from the inception of the oil industry in the United States in 1859, the total U. S. production of oil up to the end of 1930 was 13,148,472,000 barrels of 42 U.S. gallons. The estimate of known

[1] Compiled from data by U. S. Geological Survey and U. S. Bureau of Mines.

[2] For specific information on coals of the United States, the reader should consult the Bulletin of the U. S. Bureau of Mines and in particular Bulletins 22, 85, 123 and 230. Also the Keystone Coal Catalog and Buyers Guide of McGraw-Hill Catalog and Directory Co., Inc.

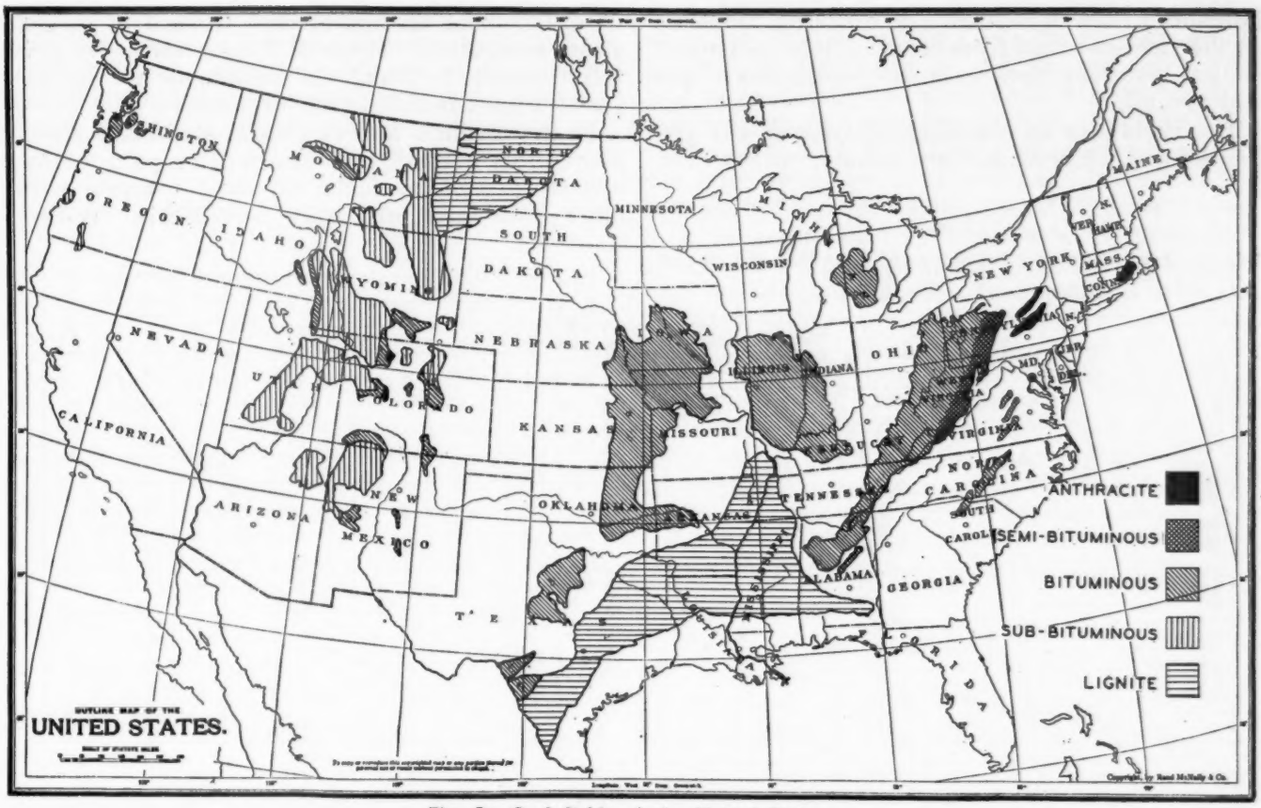



**Fig. 2—Coal fields of the United States.**

underground reserves on January 1, 1931, was approximately 10,000,000,000 barrels. The rate of production over the past 20 years is shown in Fig. 3. If we assume an average production over the next ten years of 1,000,000,000 barrels per year, the present estimated known reserves will have been exhausted in that period of time. To assume that the United States will be devoid of an underground supply of liquid oil by 1942 is far from a justifiable assumption as it is beyond the powers of any one to predict the extent of new discoveries which will be made in the meantime. Little prospecting is being done at the present time as the present overproduction difficulty of the oil industry and the low price of oil is not a condition favorable to stimulation of prospecting activities. It is a fact worth noting, however, that successive estimates of underground reserves made during the history of the industry have each shown an increase over preceding estimates, in spite of the production which has taken place during the intervening period.

TABLE 2

NATURAL FUELS USED IN PRODUCTION OF ELECTRIC POWER—1920-1930

| | Coal | | Oil | | Natural Gas | |
|---|---|---|---|---|---|---|
| Year | Thousand Tons | Per Cent | Thousand Bbl. | Per Cent | Million Cu. Ft. | Per Cent |
| 1920 | 37,124 | 90.0 | 13,123 | 7.4 | 24,702 | 2.6 |
| 1921 | 31,585 | 84.2 | 12,045 | 7.9 | 23,722 | 2.9 |
| 1922 | 34,179 | 88.9 | 13,197 | 8.0 | 27,172 | 3.1 |
| 1923 | 38,966 | 89.1 | 14,684 | 7.8 | 31,433 | 3.1 |
| 1924 | 37,556 | 86.3 | 16,630 | 8.9 | 48,443 | 4.8 |
| 1925 | 40,222 | 90.1 | 10,246 | 5.4 | 46,521 | 4.5 |
| 1926 | 41,311 | 90.2 | 9,399 | 4.8 | 53,207 | 5.6 |
| 1927 | 41,888 | 90.7 | 6,782 | 3.4 | 62,919 | 5.9 |
| 1928 | 41,350 | 89.2 | 7,156 | 3.6 | 77,326 | 7.2 |
| 1929 | 44,937 | 85.5 | 10,124 | 4.6 | 112,706 | 9.9 |
| 1930 | 42,898 | 84.6 | 9,260 | 4.4 | 120,289 | 11.0 |

Figures taken from data published by U. S. Geological Survey, Division of Power Resources.

In addition to the liquid reserves, the oil shale deposits in the United States are estimated to be good for a production of 92,000,000,000 barrels of oil and the bituminous coal deposits will yield upon distillation approximately 100,000,000,000 barrels. These secondary reserves can, however, scarcely be looked upon as sources of fuel for steam generation in competition with coal.

The relative importance of the several states in the oil producing industry is indicated in Table 6.

It will be noted that the three leading states account for 81.81 per cent of the total production.

Fuel oil is a product of the refinery. In the process of distillation, naphtha, gasoline, kerosene, distillate and gas oil follow one another in sequence as the temperature is raised. The residual is sold as fuel oil either without further distilling or after complete distillation for the purpose of recovering the final increments as lubricating oil, paraffin and other products. Practically all of the gas oil, and in addition a substantial amount of fuel oil, is used in the manufactured gas industry. In the statistics given herewith gas oil and fuel oil are grouped together as one item.

Since the introduction of "cracking" processes about 15 years ago, and the rapid increase in the demand for gasoline in proportion to crude production, the yield of kerosene has been reduced to the minimum requirements by conversion to gasoline. The lubricating fraction is as essential as gasoline, thus leaving as further stock for the cracking process, gas oil and fuel oil. Fig. 4 shows the

influence of the introduction of cracking processes on the yield obtained from crude. Note the irregular but persistent decline in the production of gas and fuel oil.

The variations in chemical analysis of gas and fuel oil are not great and are unimportant in their influence on the adaptability of the fuel for steam generation.

A typical analysis, in per cent, is carbon 85.6, hydrogen 12.2, sulphur 0.8, nitrogen 0.80, oxygen 0.60.

The physical characterictics vary rather widely and particularly the viscosity, the most important factor affecting the handling and atomizing of the oil for boiler furnaces. Fuel oil is graded according to viscosity as follows:

| | Viscosity * seconds | | Temp. at deg. fahr. | Moisture Limit per cent | Sediment Limit per cent |
|---|---|---|---|---|---|
| Bunker "A" not over | 100 | at | 77 | 1.00 | 0.25 |
| Bunker "B" not over | 100 | at | 122 | 1.00 | 0.25 |
| Bunker "C" not over | 300 | at | 122 | (——2.00——) | |

* Saybolt-Furol Viscosmeter.

All of these oils may be used successfully in boiler furnaces. The more viscous the oil the higher the pressure and temperature required. All may be handled with a limiting pressure of 300 lb. gage and a limiting temperature of 300 deg. fahr.

The consumption of gas oil and fuel oil in the United States for the year 1930 was 348,630,278 barrels. The distribution of fuel oil for various services is shown in Table 7. Note that the consumption for electric power generation is only 2.7 per cent. The corresponding figure for each of the four preceding years is as follows: 1926—2.8, 1927—2.0, 1928—2.0, 1929—2.7. The item "all other uses," includes an appreciable amount of oil for steam generation. Much of it, however, is for preferred service in which the convenience of oil fuel justifies a premium in price over coal.

In the medium and large size stationary steam plants only a small premium will be paid for the convenience of oil fuel. Oil must compete with other fuels essentially on a B.t.u. basis. With a shortage in fuel oil production only those steam plants which are remotely situated from a supply of coal will be able to afford the price.

The cheapness of transportation of fuel oil by pipe line and by water renders it accessible to practically every industrial center and particularly to those on the seaboard. During periods of overproduction it frequently becomes possible to contract for fuel oil for a period of months, or perhaps for a year or so on terms which represent a substantial saving compared with the normal fuel supply for the station.

From the foregoing it must be apparent that to build a steam plant with a prospective equipment life of 15 to 30 years or more adapted exclusively to the use of fuel oil would be, in other than exceptional circumstances, exercising very questionable judgment. Over such a period of time the availa-

TABLE 3

ESTIMATED ORIGINAL TONNAGE BY STATES AND RANK OF COAL AT CLOSE OF 1927

(In millions of net tons of 2,000 lb. each)

| State | Lignite | Sub-bituminous Coal | Bituminous Coal | Semi-bituminous Coal | Semi-anthracite and Anthracite |
|---|---|---|---|---|---|
| Alabama | ..... | ..... | 67,583 | ..... | ..... |
| Arkansas | 90 | ..... | 170 | 1,226 | 400 |
| Arizona | ..... | 1,141 | 10 | ..... | ..... |
| California | ..... | 16 | 27 | ..... | ..... |
| Colorado | ..... | 104,175 | 213,071 | ..... | 100 |
| Georgia | ..... | ..... | ..... | 933 | ..... |
| Idaho | ..... | 100 | 600 | ..... | ..... |
| Illinois | ..... | ..... | 201,400 | ..... | ..... |
| Indiana | ..... | ..... | 53,051 | ..... | ..... |
| Iowa | ..... | ..... | 29,160 | ..... | ..... |
| Kansas | ..... | ..... | 30,000 | ..... | ..... |
| Kentucky | ..... | ..... | 123,327 | ..... | ..... |
| Maryland | ..... | ..... | 1,507 | 6,536 | ..... |
| Michigan | ..... | ..... | 500 | ..... | ..... |
| Missouri | ..... | ..... | 84,000 | ..... | ..... |
| Montana | 315,474 | 62,985 | 2,655 | ..... | ..... |
| New Mexico | ..... | 172,906 | 18,925 | ..... | ..... |
| North Carolina | ..... | ..... | 200 | ..... | ..... |
| North Dakota | 600,000 | ..... | ..... | ..... | ..... |
| Ohio | ..... | ..... | 93,967 | ..... | ..... |
| Oklahoma | ..... | ..... | 46,951 | 8,000 | ..... |
| Oregon | ..... | 7,000 | 3,000 | ..... | ..... |
| Pennsylvania | ..... | ..... | 102,574 | 9,574 | 21,000 |
| South Dakota | 1,020 | ..... | ..... | ..... | ..... |
| Tennessee | ..... | ..... | 25,665 | ..... | ..... |
| Texas | 23,000 | ..... | 8,000 | ..... | ..... |
| Utah | ..... | 5,156 | 88,184 | ..... | ..... |
| Virginia | ..... | ..... | 20,749 | 400 | 900 |
| Washington | ..... | 52,542 | 11,412 | ..... | 23 |
| West Virginia | ..... | ..... | 122,644 | 29,900 | ..... |
| Wyoming | ..... | 590,160 | 80,563 | ..... | ..... |
| Miscellaneous | ..... | ..... | ..... | ..... | ..... |
| Total | 939,584 | 996,081 | 1,429,895 | 56,569 | 22,423 |

Figures taken from data published by U. S. Geological Survey.

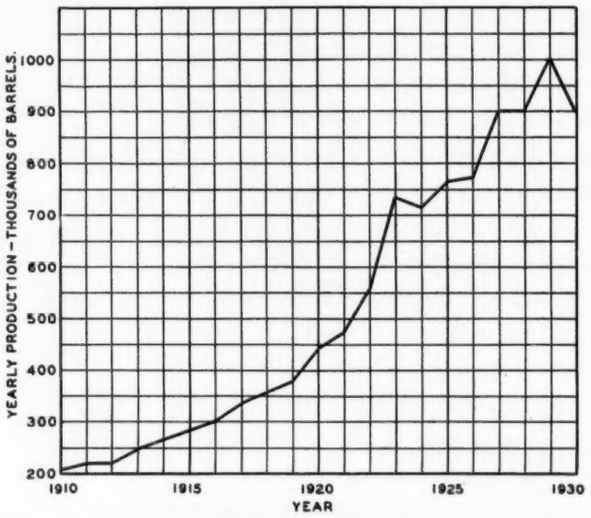



**Fig. 3—Oil production in the United States (from data published by U. S. Bureau of Mines).**

TABLE 4

DISTRIBUTION OF COAL DEPOSITS AND PRODUCTION ACTIVITY

| | Known Coal Deposits in Per Cent of Total | | Coal Production in Per Cent of Total 1926 | 1927 |
|---|---|---|---|---|
| Wyoming | 19.5 | Pennsylvania | 36.1* | 37.3* |
| North Dakota | 17.4 | West Virginia | 21.8 | 24.3 |
| Montana | 11.3 | Kentucky | 9.6 | 11.6 |
| Colorado | 9.2 | Illinois | 10.6 | 7.8 |
| Illinois | 5.8 | Ohio | 4.2 | 2.6 |
| New Mexico | 5.5 | Alabama | 3.2 | 3.3 |
| West Virginia | 4.4 | Indiana | 3.5 | 3.0 |
| Pennsylvania | 3.8 | Virginia | 2.1 | 2.2 |
| Kentucky | 3.6 | Colorado | 1.6 | 1.6 |
| Ohio | 2.7 | Wyoming | 1.0 | 1.1 |
| | 83.2 | | 94.8 | 93.7 |
| * Anthracite accounts for | | | 12.9 | 14.4 |

bility of fuel oil is questionable and the price is more than likely to fluctuate between wide limits.

Flexibility in design making the oil-fired plant readily adaptable to coal burning may be achieved at very small cost. Such flexibility should be and

TABLE 5

ANALYSES OF TYPICAL COALS LISTED GEOGRAPHICALLY FROM EAST TO WEST

| | Moisture, per cent | Volatile Matter, per cent | Fixed Carbon, per cent | Ash, per cent | Sulphur, per cent | B.t.u. per lb. | Fixed Carbon / Volatile Matter |
|---|---|---|---|---|---|---|---|
| **Pennsylvania** | | | | | | | |
| Anthracite | 1.30 | 5.68 | 85.57 | 7.14 | 0.42 | 13,777 | 15.1 |
| Sullivan County Semi-Anthracite | 3.4 | 9.3 | 75.6 | 11.7 | 0.8 | 13,120 | 8.1 |
| Cambria County Semi-Bituminous | 3.3 | 12.5 | 77.9 | 6.3 | 1.0 | 14,340 | 6.2 |
| Cambria County Bituminous | 3.1 | 26.0 | 64.4 | 6.5 | 1.4 | 14,160 | 2.5 |
| Allegheny County Bituminous | 3.7 | 34.0 | 56.8 | 5.5 | 1.4 | 13,870 | 1.7 |
| **Ohio** | | | | | | | |
| Coshocton County Bituminous | 4.5 | 38.7 | 50.8 | 6.0 | 3.6 | 12,900 | 1.3 |
| **Indiana** | | | | | | | |
| Knox Co. Bituminous | 10.6 | 38.1 | 43.0 | 8.3 | 3.7 | 11,750 | 1.1 |
| **Illinois** | | | | | | | |
| Montgomery County Bituminous | 12.7 | 35.5 | 40.2 | 11.6 | 4.2 | 10,670 | 1.1 |
| **Iowa** | | | | | | | |
| Marion Co. Bituminous | 15.7 | 36.9 | 35.8 | 11.6 | 5.1 | 10,290 | 1.0 |
| **Colorado** | | | | | | | |
| Cañon City Bituminous | 9.1 | 35.7 | 48.0 | 7.2 | 0.9 | 11,700 | 1.3 |
| Denver Sub-bituminous | 25.6 | 28.0 | 41.1 | 5.3 | 0.4 | 9,180 | 1.5 |
| **Texas** | | | | | | | |
| Milam County Lignite | 36.0 | 27.9 | 28.7 | 7.4 | 0.8 | 7,130 | 1.0 |
| **North Dakota** | | | | | | | |
| Morton County Lignite | 38.5 | 27.6 | 26.6 | 7.3 | 1.3 | 6,700 | 1.0 |

in the majority of important installations is incorporated in the design. Pulverized coal and oil may be used in the same furnace in such a manner that a change-over from one fuel to the other without losing load on the unit is possible. Oil firing and stoker firing may also be combined but will require a shut down of from 24 to 48 hours in changing from one fuel to the other to permit placing or removal of protective refractory coverings on the stoker grate surface necessary to prevent damage when burning oil.

TABLE 6

PRODUCTION OF PETROLEUM IN 1930

| | Barrels | Per Cent of Total |
|---|---|---|
| Texas | 289,965,000 | 32.35 |
| California | 228,099,000 | 25.45 |
| Oklahoma | 215,227,000 | 24.01 |
| Kansas | 41,617,000 | 4.64 |
| Louisiana | 23,107,000 | 2.58 |
| Arkansas | 19,663,000 | 2.19 |
| Wyoming | 17,846,000 | 1.99 |
| Pennsylvania | 12,797,000 | 1.43 |
| New Mexico | 10,172,000 | 1.14 |
| Kentucky | 7,345,000 | 0.82 |
| Ohio | 6,519,000 | 0.73 |
| Illinois | 5,699,000 | 0.64 |
| West Virginia | 5,092,000 | 0.57 |
| New York | 3,802,000 | 0.42 |
| Michigan | 3,509,000 | 0.39 |
| Montana | 3,139,000 | 0.35 |
| Colorado | 1,657,000 | 0.19 |
| Indiana | 991,000 | 0.11 |
| Tennessee | 19,000 | .... |

Natural gas is the ideal fuel and commands a premium in price on a B.t.u. basis for most services for which heat must be supplied by the combustion of fuel. The heating value generally speaking runs from 900 to 1200 B.t.u. with an average of about 1,000 B.t.u. per cu. ft. In rare cases the heat value runs up to 1500 to 1800 B.t.u. per cu. ft.

Natural gas is nearly always found in association with oil. States which are large producers of oil are also large producers of natural gas. In view of the high cost of transport it is natural that gas is used in large quantities near the source of production even for low grade service where it must compete with oil on a B.t.u. basis. This situation holds for the four largest producing States—Texas, Oklahoma, California and Louisiana—states which produce a large exportable surplus above local requirements and which with the exception of Oklahoma are remotely located from a supply of good coal. By reference to Table 8, it will be observed that for the year 1930 these four states produced 76 per cent of the total gas produced in the United States and used 79.2 per cent of the total gas used in the United States for electric power generation by public utili-

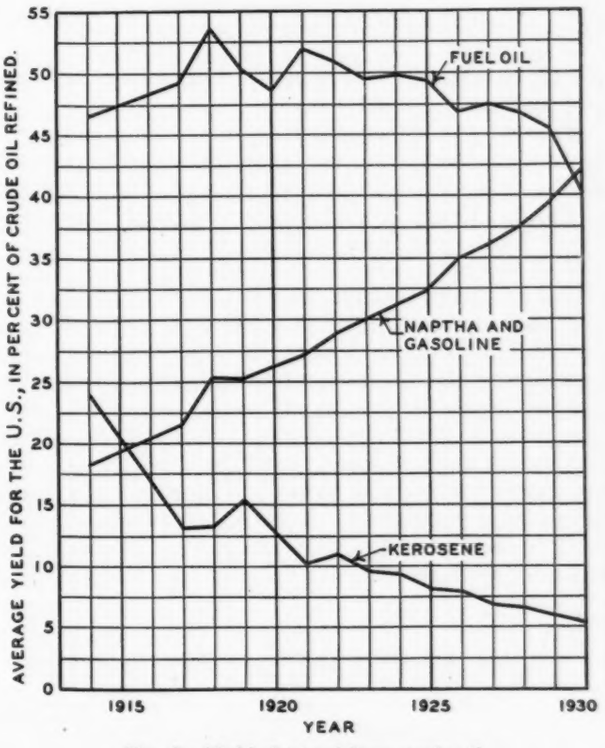



**Fig. 4—Yield obtained from crude oil.**

ties. If Kansas, which is close to the Oklahoma field, is included, the consumption for the five states for electric production is 89.7 per cent of the total used for such service.

In the eastern field, including Pennsylvania, Ohio and West Virginia, natural gas meets the competition of high grade coal and the concentration of population and industry is such as to furnish a high grade market at a good price for the entire gas output. Hence but little natural gas finds its way to the electric power plants. These three states produced in 1930 a total of 15.3 per cent of the gas produced in the United States, but used in

the electric generating plants of the public utilities only 3.8 per cent of that so used for the country as a whole.

The largest item in the cost of natural gas at points remote from the source of production is the fixed charges on the cost of the pipe line. Modern methods of constructing steel pipe has so greatly reduced this item of cost that the natural gas industry has been revolutionized. In the past few years the trunk line mileage radiating from the sources of production has been brought up to about 50,000 of

TABLE 7

DOMESTIC DELIVERIES OF GAS, OIL AND FUEL OIL IN 1930

| | 1,000 Bbl. | Per Cent |
|---|---|---|
| Steamships | 94,130 | 27.0 |
| Railroads | 67,900 | 19.4 |
| Used as fuel by oil companies | 53,437 | 15.3 |
| Manufactured gas | 18,265 | 5.2 |
| Commercial heating | 17,344 | 5.0 |
| Iron and steel products | 15.210 | 4.4 |
| Domestic heating | 9,822 | 2.8 |
| Electric power plants | 9,260 | 2.7 |
| Navy and army transports | 8,635 | 2.5 |
| All other uses | 54,627 | 15.7 |
| Total | 348,630 | 100.0 |

Figures taken from data published by U. S. Bureau of Mines.

Note.—The above table does not include 15,537,000 barrels of furnace oil (oil lighter than fuel oil) for commercial and domestic heating.

which 10,000 miles were completed during the year ending July 1st, 1931.

Natural gas transported to industrial centers remote from the source of supply cannot compete on a B.t.u. basis with coal which may be obtained close at hand. Hence under such conditions comparatively small quantities of it are used in the generation of steam in large or medium-size plants. Some plants so equipped that they can burn either gas or alternatively coal or oil at a moment's notice, and can switch from one fuel to the other without interrupting service, are in position to take advantage of "dump" rates for gas on off-peak service, i.e., during periods when the demand for gas for other services is such as not to load the pipe line. Such occasions occur daily, weekly and seasonally with dependable regularity. It therefore becomes practical to contract for off-peak gas on a profitable basis for both the user nd the pipe line owner. The

TABLE 8

NATURAL GAS PRODUCTION AND USE FOR STEAM-ELECTRIC GENERATION BY STATES IN 1930

| | Production | | Used by Electric Public Utility Plants | |
|---|---|---|---|---|
| | Billion Cu. Ft. | Per Cent | Billion Cu. Ft. | Per Cent of Total |
| Texas | 517.9 | 26.6 | 43.8 | 36.4 |
| Oklahoma | 348.1 | 17.9 | 6.7 | 5.6 |
| California | 334.8 | 17.2 | 26.2 | 21.8 |
| Louisiana | 278.3 | 14.3 | 18.6 | 15.4 |
| West Virginia | 144.2 | 7.4 | 0.1 | 0.1 |
| Pennsylvania | 88.7 | 4.6 | 0.1 | 0.1 |
| Ohio | 63.4 | 3.3 | 4.3 | 3.6 |
| Wyoming | 43.2 | 2.2 | 0.2 | 0.2 |
| Kansas | 37.6 | 1.9 | 12.6 | 10.5 |
| Kentucky | 28.0 | 1.4 | 0.0 | 0.0 |
| Arkansas | 18.6 | 1.0 | 1.5 | 1.2 |
| Others | 40.6 | 2.2 | 6.2 | 5.1 |
| Total | 1,943.4 | 100.0 | 120.3 | 100.0 |

phenomenal increase in the use of gas for steam generation is due partially to this but more to the greater radius from the sources of production which may be served by modern pipe line construction in competition with other fuels. Gas may be transported on a B.t.u. and mileage basis as cheap as, or cheaper than coal i.e., gas can successfully compete with coal at any point which is as far from the coal mine as it is from the gas well.

The ultimate reserve of natural gas is a matter of speculation. Enormous reserves have been established for serving the newly constructed pipe lines but the ultimate date of exhaustion is very uncertain. The most conservative estimate of present gas reserves is about 20,000,000,000,000 cu. ft., or about ten times the present annual production. The amount of gas yet to be discovered, however, is beyond the powers of prediction.

Equally important with the available supply is the rate of consumption. New pipe lines are still being built and those already built are not yet loaded to capacity, particularly for off-peak service. It therefore becomes difficult to predict what the annual consumption is likely to be ten years hence. With both the ultimate supply and the rate of consumption so uncertain the ultimate date of exhaustion is a matter of speculation.

One thing is certain and that is that with a decline in production there will be less and less available for steam generation at a price which will compete with coal.

TABLE 9

DOMESTIC DELIVERIES OF NATURAL GAS FOR U. S. A.

| | 1929 | | 1930 | |
|---|---|---|---|---|
| Service | Billion Cu. Ft. | Per Cent | Billion Cu. Ft. | Per Cent |
| Field (drilling, pumping, operating gasoline plants, etc.) | 705 | 36.8 | 723 | 37.2 |
| Domestic (including commercial) | 360 | 18.8 | 377 | 19.4 |
| Manufacture of carbon block | 261 | 13.6 | 267 | 13.8 |
| Electric public utility power plants | 112 | 5.8 | 120 | 6.2 |
| Petroleum refineries | 104 | 5.4 | 99 | 5.1 |
| Portland cement plants | 42 | 2.2 | 41 | 2.1 |
| Other industrial | 333 | 17.4 | 315 | 16.2 |
| | 1,917 | | 1,942 | |

Figures taken from data published by U. S. Bureau of Mines.

Note.—"Other industrial" includes an appreciable amount of gas used in the manufacture of carbon block and in the cement industry.

Table 2 shows the extent to which natural gas is being used by public-utility steam plants. Table 9 shows the part this same gas represents of the total natural gas production.

From the above it will be apparent that of the three natural fuels coal is the only one the future of which is certain for many generations to come. The continuity of oil and gas supplies for steam generation at prices which make them attractive in competition with coal over a period of years is very uncertain. Therefore in building steam plants it seems highly desirable that however strongly present conditions may favor either oil or natural gas, the design should not close the door on the future use of coal. Conversely the design of the coal burning plant should take into serious consideration the desirability of being able to switch quickly and at small expense to natural gas or oil either for continuous service or in the case of natural gas, for daily, weekly or seasonal off-peak service. The desirability of such flexibility was never so apparent as under present economic conditions. The cost of obtaining it in new designs is insignificant.

# Power Station Design in Great Britain

By DAVID BROWNLIE
London

**Mr. Brownlie discusses the principal features of a number of the leading British power stations and of two outstanding industrial plants. Some of these plants are still in process of installation. The trends indicated are for the most part, moderate pressures with high superheat, divided opinion as to methods of firing and steam reheating, treatment of stack gases to remove sulphur compounds, and, in some instances, chlorination of condenser water. It is quite apparent from this article that Great Britain is proceeding in a substantial way with its plans for national electrifcation.**

IN spite of the world depression, steady progress continues to be made with the electrification of Great Britain, which of course involves new power stations and extensions to many existing stations.

Accordingly it will be interesting to give an outline of the latest tendencies in British power station practice as represented by a number of new plants now being erected or only recently completed. In this connection reference will be made to *Kirkstall,* Leeds, *Clarence Dock,* Liverpool, just recently completed, *Dunston B,* Newcastle, *Battersea,* London, *Fulham,* London, *Barking* extensions, London, and *Iron Bridge,* near Shrewsbury, now in course of erection, as well as to *Kearsley,* near Manchester, and *Deptford West,* London, which have been running some time; in the industrial field to the Ford plant, in process of erection at Dagenham, near London, and the Synthetic Ammonia and Nitrates, Ltd. plant at Billingham-on-Tees, completed in 1930.

These stations, with others in addition, show, as the chief characteristics of British practice, a gradual increase in steam pressures, although not to the same extent as in the United States, and very high superheat, say 800 to 850 deg. fahr. Also dust separating systems, mostly on the centrifugal principle without water jets, are being rapidly adopted, and well over 50 British stations are already equipped. In addition much attention is being given to scrubbing chimney gases with water to remove acid sulphur compounds.

The practice of treatment of cooling water with a measured trace of chlorine gas, having as the primary object the prevention of organic growths on the condenser tubes, continues to make progress.

The gilled steel tube economizer is now preferred to the high-pressure cast iron designs and generally both air heaters and economizers are used. The adoption of reheating, however, is still slow.

More difference of opinion than ever now exists as to the best method of firing, not only mechanical stoking versus pulverized fuel firing, but also as regards the different methods in each field. We have now reached the stage in Great Britain when no very definite preference exists for traveling grate stokers, multiple retort stokers, storage pulverized fuel systems, or direct fired pulverized fuel systems. Thus individual British stations, just as in the United States, France, and Germany, have adopted one system and then added another alongside, and in some instances the same companies have all three methods in operation in their various plants.

In the opinion of the writer, the main tendencies in Great Britain during the past year or two are a decline in pulverized fuel as compared with mechanical stoking, while in the latter field the multiple retort stoker has made some advance, although the traveling grate type has long been most in favor. The direct fired pulverized fuel system has also advanced rapidly at the expense of the storage or bin and feeder system. It must be emphasized, however, that all four methods of fuel burning have been improved in design, and in methods of operation and control, so that in each case with the aid of water-cooled furnace walls, automatic control equipment, and other refinements, over all efficiencies of 82-90 per cent are being obtained in continuous commercial operation.

The rapid growth in the electrification of Great Britain is shown by the recent issue by the Central Electricity Board of $35,000,000 of Central Electricity 5 per cent stock 1955-1975 at a price of 95 per cent, this having been handled by the Bank of England.

Essentially the Central Electricity Board, constituted by the Electricity Supply Act of 1926, are carrying out the erection of the overhead "grid" system all over Great Britain, and they are empowered, with the consent of the Electricity Commissioners (British Government) to borrow up to $250,000,000 for this purpose. Already there has been involved in this connection a total sum of $164,000,000, of which $37,500,000 is in respect of

the standardization of frequency and $126,500,000 for the construction and acquisition of main transmission lines.

For this work 3928 miles of overhead main transmission lines have been specified, of which 2310 miles are already constructed with 910 miles in operation, while the total amount of electricity generated in Great Britain since 1922 by authorized

**Kirkstall station—view at burner level.**

undertakings and railway and tramway authorities, but not including all the private power stations and plants, is as follows:

| *Year Ended* | *Units Generated* |
|---|---|
| March 31, 1922 | 4,884,660,038 |
| March 31, 1923 | 5,738,718,485 |
| March 31, 1924 | 6,681,524,272 |
| March 31, 1925 | 7,415,375,529 |
| March 31, 1926 | 8,122,961,823 |
| March 31, 1927 | 8,365,857,198 |
| March 31, 1928 | 9,927,850,630 |
| March 31, 1929 | 10,878,980,925 |
| March 31, 1930 | 11,961,621,965 |
| December 31, 1930 | 12,332,949,844 |
| December 31, 1931 (estimated) | 12,820,000,000 |

Taking now individual stations, the first section of Kirkstall, Leeds, which came into operation last year, includes three bent tube boilers, each of 160,000 lb. evaporation per hr. normal and 184,000 lb. overload, operating at 490 lb. pressure and 750 deg. fahr. superheated steam temperature, with both air heaters and feedwater economizers. These boilers are fired with pulverized fuel (storage type) and there are separate rotary dryers for the coal. Centrifugal dust collectors are installed. The generating equipment consists of two turbo-generators of 25,000 kw. each.

The new Clarence Dock Station, belonging to the Corporation of Liverpool, will be eventually 400,000 kw., and will contain 32 water-tube boilers and 8 turbo-generators each of 50,000 kw. The present first section consists of four horizontal tube boilers and two 50,000 kw. turbo-generators, of which only one is operated at a time. The boilers have an evaporation of 160,000 lb. per hr. each and 175,000 lb. overload, running at 450 lb. pressure and 750 deg. fahr. superheated steam temperature, which, however, is to be raised in the immediate future to 825 deg. fahr. The firing is by means of traveling grate stokers, while in addition each boiler has one unit pulverizer with two burners, to take the peak load. Air heaters and steel tube economizers are installed.

This plant utilizes a special method of washing the combustion gases with water jets, designed by H. L. Robinson, the Chief Engineer. A Chloronome plant for sterilizing the cooling water is installed, using approximately 0.50 parts of chlorine per 1,000,000 parts of water.

By September, 1932, the first section of the new Dunston B Station of the Newcastle-on-Tyne Electric Supply Company is to be completed, consisting of 12 water-tube boilers operating at 625 lb. pressure and 825 deg. fahr. superheated steam temperature. The chief features of this important new station may be summed up as moderate steam pressure, high temperature of superheated steam, reheating between the stages of the turbine, and the use of traveling grate stokers for some of the boilers and unit pulverizers for the rest. The generating equipment consists of three turbo-generators of 50,000 kw. each to be operated at 600 lb. pressure and 800 deg. fahr. at the stop valve.

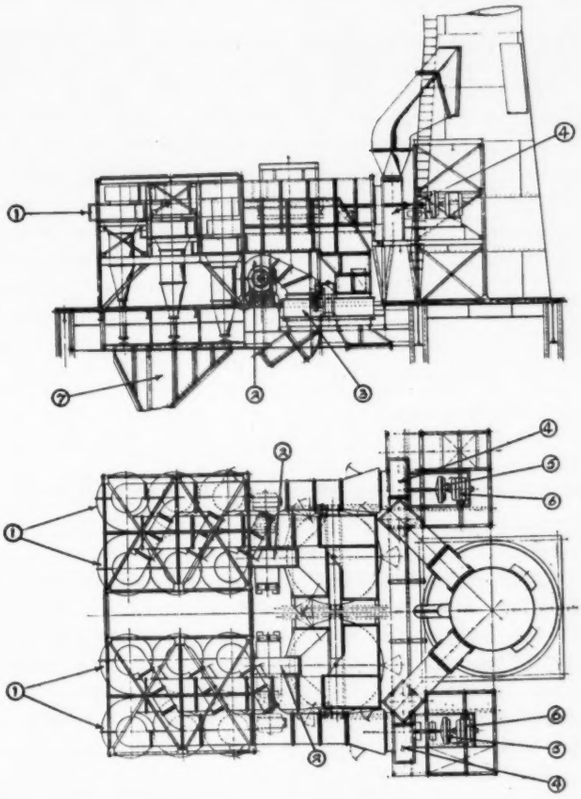
Provision is made for reheating of the steam from 525 to 825 deg. fahr. Each turbine is of the 2-cylinder tandem type, running at 1500 r.p.m., the steam being returned for reheating at 120 lb. pressure. The present plans are for Dunston B to be extended to 300,000 kw., although this will probably be exceeded.

Six of the boilers are designed for 156,000 lb. normal evaporation, while the other six, which are combined steam generators and reheaters, will each generate 125,000 lb. of steam per hr., in addition to the raising of 200,000 lb. of steam at 150 lb. pressure from 525 to 825 deg. fahr. Eight of the boilers are to be operated by traveling grate stokers and the other four boilers by unit pulverizers. All the boilers have extra large combustion chambers with water-cooled walls, and will be equipped with superheaters, air heaters and economizers. This plant will be equipped with 72 dust collectors arranged in groups of six each in parallel to the boilers; these are being installed in accordance with the latest practice before the induced draft fans, so as to prevent erosion of the latter by the dust.

The new Battersea Power Station of the London Power Company is also to be running by the end of 1932 and is designed for an ultimate capacity of 400,000 kw., the present first section being 130,000 kw., which is provided by two 65,000 kw. turbo-

generators, with space for the immediate addition of a third. The chief interest of course in connection with Battersea is the very large equipment being constructed for the washing of the flue gases with hot water at 160 to 180 deg. fahr., to remove all the acid sulphur compounds. Similar plants are under construction at the Deptford and Willesden Power Stations, belonging to the same Company, following upon the original experimental work at the Grove Road Station.

The latest details are difficult to obtain, but apparently 17 to 22 tons of hot water at 160 to 180 deg. fahr., is to be used, per ton of coal burned unless it will be possible to reduce the amount by the employment of catalysts along the lines of the work being undertaken at the University of Illinois. In this connection it is interesting to learn from the London Power Co., Ltd., that a higher elimination



1. Battery of dust collectors
2. Forced draft fans.
3. Air preheater.
4. Induced draft fans.
5. Hydraulic variable speed couplings.
6. Induced draft fan motors.
7. Dust hopper

**Iron Bridge station—views showing arrangement of dust collectors before induced draft fans.**

of sulphur from combustion gases can be obtained when the $CO_2$ content is reduced to about 9 per cent, that is when the oxygen content is increased to 10 to 11 per cent, by adding air before washing, or preferably aerating the wash water.

Much more information, however, is wanted on the whole question of scrubbing combustion gases with water or dilute solutions, especially in the way of capital and operating costs, and probably difficulties in the way of corrosion, reduction of the natural draft because of the lowering of the temperature, and the tendency to a deposition of dirty rain outside the top of the chimney.

In London also consent has been given by the Electricity Commissioners for the erection by the Fulham Borough Council of a new power station at Fulham, on the Thames, which is to be 300,000 kw. with five 60,000 kw. turbo-generators and 16 boilers each of 350,000 lb. evaporation per hour, operating at 600 lb. pressure. This is to include another method of scrubbing the gases with water to remove the acid sulphur compounds, but full details with regard to Fulham are not yet available, much opposition having been aroused against this scheme, as also in the case of Battersea, because of the pollution of the atmosphere.

Particularly interesting are the present extensions at the Barking Power Station of the County of London Electricity Supply Co. Ltd., comprising 150,000 kw., to be ready next winter, which will bring the station up to 390,000 kw., with plans also for the erection of another 150,000 kw. after 1932, making a total ultimate capacity of 540,000 kw., which would make this the largest power plant in the British Empire. The main features of the extensions in hand, comprising the third section of the station, are medium pressure, high temperature of superheat, medium-size boilers, mechanical stoking on the traveling grate principle, and absence of reheating. It is the intention to run this 150,000 kw. extension as the base line portion of the station at 50 per cent load factor, as compared with 35 per cent load factor for the whole plant, and under these conditions it is the opinion that traveling grate stokers operating continuously at steady load are the best proposition in this case, superior to multiple retort stokers and also pulverized fuel firing.

The equipment now being installed comprises eight boilers, each of 256,000 lb. normal evaporation per hr., operating at 625 lb. pressure and 800 deg. fahr. steam temperature, with water-cooled walls, steel tube feedwater economizers, superheaters, air heaters, and traveling grate stokers. Also there are two turbo-generators of 75,000 kw. each, the largest yet constructed in Great Britain.

The No. 1 section at Barking consists of 12 boilers and 4 combined steam reheater and boiler units running at 375 lb. pressure and 750 deg. fahr. superheated steam temperature. All sixteen boilers are fired by traveling grate stokers, the evaporation in each case being 75,000 lb. per boiler per hr.

The second section at Barking consists of 10 boilers at 375 lb. pressure and 725 deg. fahr. superheated steam temperature, with bin and feeder pulverized fuel firing, the rated evaporation of each boiler being 135,000 lb. per hr. The total generating plant of 240,000 kw. is made up of four 40,000 kw. turbo-generators and four 20,000 kw. turbo-generators. The first section of the new Iron Bridge Station on the River Severn, belonging to the West Midlands Joint Electricity Authority, is particularly interesting because it will be the first plant in the world to be operated with centrifugal dust collec-

tors installed before the induced draft fans to prevent erosion, on the same lines as at Dunston B. The steam generating plant consists of three bent tube boilers of 225,000 lb. normal evaporation each and 275,000 lb. overload, running at 400 lb. pressure and 800 deg. fahr. superheated steam temperature, each fired with three unit pulverizers with six burners per boiler. The dust collectors are 36 in number, that is 12 per boiler, arranged in two sets of six each in parallel before the induced draft fans, as stated. A 50,000 kw. turbo-generator is to be installed, which includes 4-stage feedwater heating and reheating between the stages.

Considerable interest attaches to the Deptford West Power Station on the Thames, of the London Power Company Ltd., as this is one of the most efficient in Great Britain. For example, during a run of ten months ending October 31, 1931, in which there was a total output of 254,766,820 kw-hr., and a consumption of 121,946 tons of coal and 25,297 tons of gasworks coke, the net thermal efficiency per kw-hr. generated was 23.842 per cent, and 22.821 per cent for power delivered to the feeders. Also the boiler efficiency was 82.48 per cent, and practically the same results are given for a previous twelve months' period, ending December 31, 1930, which showed a thermal efficiency of 22.072 per cent per kw-hr. delivered to the feeders. Generally the gross overall thermal efficiency of steam generation varies from 86.43 to 87.51 per cent. Deptford West is one of the best equipped power stations in Great Britain from the point of view of taking continuous accurate records.

It will be remembered from a previous contribution that the most efficient power station in Great Britain for the year ending December 31, 1930 was Kearsley, near Manchester, the figure being 23.84 per cent. This plant is equipped with traveling grate stokers, with steam generating conditions of 315 lb. pressure, 685 deg. fahr. superheated steam temperature and moderate air preheating. This is a relatively small plant (only 64,000 kw.) operating under easy conditions at moderate ratings.

It is difficult to describe in a short space the power equipment of the Deptford West Station because of the different sizes of the boilers, but essentially the operating conditions are 375 lb. pressure and 780 deg. fahr. superheated steam temperature. There are 12 boilers, and extensions now being completed will add four more. The firing equipment includes both traveling grate and multiple retort stokers. An interesting feature of the plant is an elaborate system of closed circuit feedwater heating.

The new Ford plant at Dagenham is one of the most interesting and important industrial installations in the world. It consists of three very high pressure boilers of 1200 lb. per sq. in., and a turbo-generator of 30,000 kw., discharging at 200 lb. per sq. in. to the general heating and process mains, this steam supply being augmented by two other water-tube boilers of 200 lb. per sq. in. Each of the high-pressure boilers will have a normal output of 205,000 lb. of steam per hr. Four separate fuels are to be used, i.e., pulverized coal, coke, blast furnace gas, and town's refuse.

Also of great interest is the plant of Synthetic Ammonia and Nitrates Ltd., of Billingham-on-Tees, which has eight forged-drum water-tube boilers operating at 800 lb. steam pressure and 856 deg. fahr. superheated steam temperature, fired with pulverized fuel, on the storage principle. Each boiler has an evaporation of 215,000 lb. of water per hr. and 269,000 lb. overload. The equipment includes gilled-tube steaming economizers, air heaters, superheaters, 7-stage feedwater heating, and plant for the provision of pure distilled make-up water having a capacity of 2500 metric tons (2204 lb.) per 24 hr.

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**The Hagan Corporation** announces the appointment to its Pittsburgh sales engineering department of E. W. Wagenseil who was, for the past five years, in charge of air preheater sales for Blaw-Knox Company. For 18 years before coming to Blaw-Knox Company, Mr. Wagenseil was engaged in Stoker Engineering and Sales, having been Westinghouse representative at Chicago and later sales manager of the Harrington Stoker. His work during the past five years with Blaw-Knox Company was principally concerned with the application of preheated air to heating furnaces, soaking pits, etc., in the steel industry.

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## National Process Meeting in Buffalo, N. Y., June 6-7

An interesting session has been arranged for the National Process Meeting to be held in Buffalo, June 6 and 7. Several important papers will be presented. The paper on flow data will be entitled "Flow of Gases and Liquids in Closed Conduits" and is being prepared by R. J. S. Pigott, of the Gulf Refining Co. It will give the results of studies on the flow of liquids and gases in closed conduits, varying from smooth brass pipe to brick ducts. The paper will attempt to collect available authoritative data, particularly with a view to settling the effect of roughness of the conduit.

The paper on alignment charts is being prepared by T. H. Chilton, A. P. Colburn, R. P. Genereaux and H. C. Vernon, of the DuPont Co. These alignment charts have been developed by them for use in fluid-flow and heat transfer problems. Charts will be included on Pressure Drop in Clean Steel Pipe, Turbulent Region; Film Coefficient of Heat Transfer, Gases Flowing Through Tubes; Design Chart; Gases in Tubes; Film Coefficient of Heat Transfer, Gases Flowing Across Tube Banks; Free Convection Outside Horizontal Cylinders; Free Convection, Vertical Surfaces; and Film Coefficient of Heat Transfer, Condensing Vapors.

# REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured from
In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

## Examination of Water

**(Chemical and Bacteriological)**

**By William P. Mason**
**Revised by Arthur M. Buswell**

THIS is the sixth revised edition of Mason's work which has been considered a standard text on this subject for more than a generation, and few books relating to water analysis have had such a wide appeal.

Although changes and additions have modernized the book completely, the method of presentation and spirit of the first edition have been kept the same. The aim of the book remains unchanged —to give suggestions for the determination of mineral matters in water and present such material on the bacteriological examination as has been demonstrated to be of real service to the water examiner. New methods which were unknown at the time of the publication of the original edition have been added. The appendix, which is new, contains methods of procedure giving details of making analyses taken from authoritative sources and also contains a summary of bacteriological analysis. A more extensive discussion of losses due to hard water and detailed directions for the systematic analysis of boiler waters have been included.

Of special assistance to students, engineers and chemists who possess no special training in water purification but who are reponsible for the control of water-treating systems, is chapter four, relating to laboratory exercises for water treatment.

Book contains 224 pages, size 6 x 9, bound in red buckram, price $3.00.

## Electrical Phenomena in Gases

**By Karl Kelchner Darrow**

PHYSICISTS, chemists and many workers in industrial laboratories will welcome an inclusive treatment from the pen of a scientist so widely known as the author, research physicist at the Bell Telephone Laboratories. Few subjects evoke a livelier interest and the literature, except in the form of scattered articles on various phases of the subject, is scant indeed. The work is addressed to the elucidation of the general principles of the conduction of electricity through gases, and the description and discussion of methods and experiments. Dr. Darrow has spent much time in the preparation of the present volume. Perhaps no happier selection of author could have been made, for Dr. Darrow not only is thoroughly familiar with the recent developments on the subject but has written and lectured on various parts of the field for a number of years. He has written a book which is the latest authoritative word on a subject of wide interest to physicists and chemists.

The book is bound in green silk, size 6 x 9, 500 pages, 88 engravings, 9 halftones; price $8.00.

## Smoke

**(A Study of Aerial Disperse Systems)**

**By R. Whytlaw-Gray and H. S. Patterson**

ALTHOUGH in the past much attention has been directed to practical problems connected with smoke, few attempts have been made to explain the behavior of smoke in terms of general principles, or even to correlate its properties with the number, size, and nature of its constituent particles. An admirable account of all the work done on the subject up to 1924 is given in Dr. Gibbs' book *Clouds and Smokes* and a perusal of this shows that whilst many technical processes have been devised for dealing with various types of aerial suspensions little direct experimental evidence is available on the many basic features they have in common.

This book is a contribution to the scientific study of smoke. In it these systems are considered as a special type of disperse material and the authors have attempted to indicate how far the parallelism between aerial and aqueous suspensions implied in the term "aerosol" really extends. Hitherto few investigations of this character have been published and in consequence most of the book treats of work carried out at Leeds (England) during the past few years. Although it is clear that much remains to be done, and the book covers only a general survey of a wide territory, the authors have explored some of its main features and have worked out methods which pave the way for future advances. Chapter headings as follows: Early investigations on Smoke: Errors in Counting in Smokes; Present Methods of Counting Particles; The Coagulation of Smokes; The Theory of Coagulation; The Formation of Smokes; The Structure of Smoke Particles; The Determination of Weight Concentration; The Size and Density of Smoke Particles; Size Distribution in Smokes; Photophoresis; The Scattering of Light by Smokes; The Electrification of Smoke Particles; The Evaporation of Droplets; Further Problems; Author and Subject Index.

Book is bound in cloth, size 5½ x 8½, contains 192 pages; diagrams and plates. Price $4.50.

# NEW CATALOGS AND BULLETINS

**Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine**

### Bolted Joints

Alco Bolted Joints is the name of a pamphlet issued by the Alco Products Incorporated. This pamphlet describes and illustrates various types of Alco Joints and lists the features claimed, some of which are as follows: narrow and thin metal gaskets, gaskets under high compression, nubbing in face of flange cuts into gasket when joint is tightened making an effective seal, hook bolt joints quickly and easily assembled and disassembled. 4 pages, 8½ x 11—Alco Products Incorporated, 220 East 42 Street, New York.

### Combination Burning of Blast Furnace Gas and Pulverized Fuel

A reprint has been recently published by Combustion Engineering Corporation describing test data on a steam generating unit fired by blast furnace gas and pulverized fuel in combination. The latter part of the article is devoted to a description of a control system which has been successfully applied to such installations. The concluding paragraphs discuss recent developments in furnace design and methods of firing which are being applied with marked success in plants using coal and gas in combination. 8 pages, 8½ x 11—Combustion Engineering Corporation, 200 Madison Avenue, New York.

### Filtration Equipment

Water Filters and Filtration Equipment is the title of a new bulletin describing the principles of filtration, the pretreatment of different classes of waters, the various types of chemical feeds, vertical and horizontal pressure filters, concrete and wood gravity filters, activated carbon filters, etc. 28 pages, 8½ x 11—The Permutit Company, 440 Fourth Avenue, New York.

### Free Vane Recorder Controller

Catalog No. 4001 describes the Bristol Free Vane Air Operated Recorder Controller. The principle employed in this controller is a new departure in pneumatic control. It permits one actuating element to move a penarm making a chart record, and to operate a control system. Furthermore, the free vane principle of control does not require any work to be done by the actuating element. Consequently, the recording mechanism is unimpeded and gives a true record of the temperature or pressure. This catalog is very comprehensive as it describes the various types of controllers and includes charts and tables. 24 pages and cover, 8½ x 11—The Bristol Company, Waterbury, Connecticut.

### Lubrication

A pamphlet entitled Systematic Lubrication for your Machinery has been issued by the Alemite Corporation. This booklet describes the various equipment for lubrication and also includes the following discussions: "Why Positive Lubrication?" "High Pressure Methods." 14 pages, 8½ x 11—Alemite Corporation, 2650 North Crawford Avenue, Chicago, Illinois.

### Magnesite Brick

Reprints entitled New Developments in Unburned Magnesite Brick for the Metallurgical Industry have been recently issued by the General Refractories Company. Copies of this reprint will be sent upon request by the manufacturer. 12 pages and cover, 8½ x 11—General Refractories Company, 106 South 16th Street, Philadelphia.

### Photoelectric Recorder

A pamphlet recently issued by the General Electric Company describes the new G-E Photoelectric Recorder. This recorder is characterized by extreme sensitivity. It is entirely self-contained, requiring no batteries for its operation. It can be furnished to operate on a circuit of any standard frequency or voltage. The partial list of quantities that can be recorded is as follows: current, voltage, illumination, vibration, noise, diameter of ball bearings, cylinders, wire, etc. 4 pages, 8½ x 11—General Electric Company, Schenectady, N. Y.

### Protective Coatings

An interesting circular has recently been issued by Cheesman-Elliot Company describing CE-CO Hi-Degree Gray Coating which will withstand temperatures of 1500 deg. fahr. and even higher. Representative plants in which CE-CO Heat Resisting Paints are being used are included. 4 pages, 8½ x 11—Cheesman-Elliot Company, 639 Kent Avenue, Brooklyn, N. Y.

### Refractories

A pamphlet has recently been issued by the Laclede-Christy Clay Products Company describing the Laclede Mullite, a super-refractory at low cost. A radical departure from former manufacturing processes has made it possible to market the brick at a price only slightly higher than first quality fire brick. Resistance to spalling caused by temperature changes, ability to withstand very high temperatures without shrinking or deforming, and resistance to attack by molten slags are some of the qualities claimed for this brick. 4 pages, 8½ x 11—Laclede-Christy Clay Products Company, St. Louis.

### Steam Plant Modernization

The article entitled "Modernizing the Old Boiler Plant" which appeared recently, has been reprinted by Combustion Engineering Corporation. This article describes the details of several actual cases in which substantial economies followed the adoption of a simple but careful developed modernization plan. In each case not only was the full cost of operating the unit after modernization less than that before, but the quantity of steam produced was substantially increased. 8 pages, 8½ x 11—Combustion Engineering Corporation, 200 Madison Avenue, New York.

### Steam Trap

The Armstrong Steam Trap is the title of a pamphlet recently issued by the Armstrong Machine Works. This pamphlet describes the Armstrong Steam Trap with the newly developed free floating lever principle. Tables giving sizes, capacities, prices, pressures and temperatures are included. 4 pages, 8½ x 11—Armstrong Machine Works, Three Rivers, Michigan.

### Tube Timing Control

Bulletin No. 13101 entitled New Cutler-Hammer Tube Timing Control describes the new tube control for welder service. The accuracy of this timing control is consistent within a fraction of a second regardless of severity of service. 4 pages, 8½ x 11—Cutler-Hammer, 12th and St. Paul Ave., Milwaukee, Wis.

### Water Level Recorders

Bulletin No. 112 describes the Bailey Boiler Water Level Recorders. This booklet outlines the advantages, the mechanical construction and the various methods of installation of the Bailey Boiler Water Level Recorders. It describes the method for obtaining records of the true water level throughout the full range of the drum. A large number of illustrations are included showing installation photographs and reproductions of actual chart records. 8 pages, 8½ x 11—Bailey Meter Company, 1050 Ivanhoe Road, Cleveland, Ohio.

## NOTICE

**Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to**

**COMBUSTION**
**200 Madison Ave., New York**

# NEW EQUIPMENT

**of interest to steam plant Engineers**

## Boiler Water Hydrometer

It is well-known that if the concentration of mineral salts in steam boilers is allowed to reach a given density, the inevitable result is foaming, priming, wet steam and a reduction in boiler efficiency. It is, therefore, of utmost importance to know when to blow down the boiler and this information can be obtained only by making regular tests of the concentration.

In order to provide power plant operators with a quick, easy and accurate method of making these tests, E. Edelmann & Co., 2332 Logan Blvd., Chicago, have perfected the No. 62 Boiler Test-O-Meter. This instrument provides a means of withdrawing and holding the water. It has a built-in thermometer scaled from 60 deg. fahr. to 120 deg. fahr., and a test may be made at any temperature within that range. This is an outstanding improvement as practically all hydrometers are calibrated to test at only one temperature.

Dirty water never touches the scale of the thermometer of the Boiler Test-O-Meter. It is always visible and easy to read.

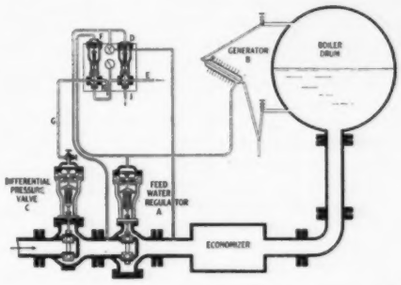
The Boiler Test-O-Meter has a built-in correction table which acting in combination with the thermometer shows at a glance the amount to subtract from the float reading to determine the concentration. It is likewise equipped with a conversion table, built into the jar containing the thermometer and correction scale, which tells the amount of concentration of the mineral salts in both grains per U. S. gallon and parts per million. No calculations are necessary in making a test with the Boiler Test-O-Meter. The operator does not have to be an expert to use it. It is a regular laboratory, incorporated in one compact unit, which entirely eliminates the necessity of having an extra beaker or jar to hold the water, an extra thermometer to take the temperature of the water and a separate conversion table.

## Feed Water Regulation Equipment

The Swartwout Company, 18511 Euclid Avenue, Cleveland, Ohio, have made new developments in their boiler feedwater regulation equipment.

The "S-C" Feedwater Regulator uses a new type of differential valve in order to overcome the disadvantages of the old differential valves. This new valve is the "S-C" Differential Type Master Control, which is essentially a pressure amplifier. Comparatively insignificant fluctuations in differential pressure are magnified, and these enlarged fluctuations are used to operate the differential pressure valve.

In the accompanying diagram, "A" represents an "S-C" Feedwater Regulator




operated by its Generator "B." It is the pressure drop across "A" that it is desired to maintain constant. This is done by controlling the Valve "C" which in turn is governed by the differential pressure master control valve "D."

Pressure is brought in through the pipe "E." This operating pressure can be any dependable source of steam, water, or air, ranging from 80 lb. to 250 lb. This operating pressure passes through the valve body of "D," on through the body of the valve "F" (which normally offers it free passage), and through the pipe "G" to the diaphragm of the valve "C." The two sides of the diaphragm of the valve "D" are connected respectively to the inlet and outlet of the feedwater regulator valve "A." As a result, the net differential pressure across the valve "A" results in a moving force to actuate the differential type master control valve "D."

The valve "C" is maintained in such a position that the differential across the feedwater regulator valve "A" is constant. Should this differential pressure tend to rise, it causes the stem of the master control valve "D" to move in a downward direction. This reduces the venting effect through the pipe "J," and admits more pressure through the pipe "E," thus increasing the pressure traveling through the pipe "G" to the diaphragm "C," and so begins to close the valve "C." Conversely, a decrease in the differential pressure across the feedwater regulator valve "A" opens the valve "C."

The setting of the master control valve "D" and the differential pressure valve "C" is such that the lowest possible differential is maintained consistent with feeding the boiler under all normal loads. This permits a relatively wide opening of the feedwater regulator valve "A." But provision must be made for feeding the boiler under abnormally high load conditions.

A second master control valve "F" is interposed in the piping between the master control valve "D" and the diaphragm of the differential valve "C." The diaphragm of the valve "F" is connected into the same generator system which controls the feedwater regulator valve "A." Springs are so adjusted that at all fluctuations in normal water level the stem of the valve "F" will remain in its highest position, and a free passage opened through the body of the valve "F" for the intermediate pressure between the master control valve "D" and the diaphragm of the differential valve "C." But when the water level in the boiler goes still lower, the increased generator pressure in "B" reacts upon the diaphragm of the master control valve "F" and starts to move it in the downward direction. This movement begins to close off the supply of intermediate pressure to the pipe "G" and the diaphragm of the valve "C," and starts to vent this pressure through the pipe "K." This starts to open the valve "C," and this action goes on progressively until it is wide open and the full pump discharge pressure is available to force water through the body of the feedwater regulator valve "A," which is itself wide open.

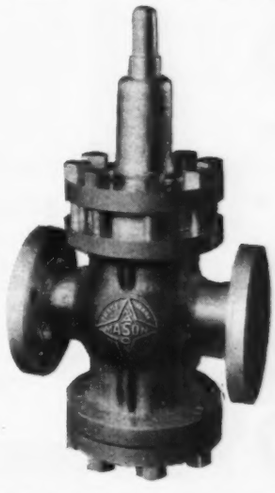
In this way the boiler is protected in an emergency by having a free opening directly through all valves from the pump discharge to the boiler drum. Since all "S-C" Valves are capable of opening the full pipe area if the quantities of water to be handled demand it, it is readily seen how well the boiler is protected against low water.

## Reducing Valve

A new reducing valve has been developed by the Mason Regulator Company, 1190 Adams Street, Boston, Massachusetts. This valve has been designed to reduce inlet pressures up to 600 lb. with temperatures up to a total of 750 deg. fahr. to any constant lower pressure.

Specifications are as follows: *Body*—Chrome-Molybdenum Steel (High Tensile Strength); *Valves*—Nitrided Tungsten-Alloy Steel (New Superhard Metal); *Valve Seat Rings, Piston, Piston Liner*—Stainless steel (Non-Corrosive).

Valve bodies have a homogeneous grain structure relieved of all internal stresses and strains by scientific heat treatment insuring accurate machining and freedom



from leakage after valves are ground in.

This valve is simple, compact and can be disassembled with ease.

The spring-pressure adjusting screw is enclosed in a protective cap which may be padlocked in place to guard against tampering.

# BOOKS . FOR . THE . ENGINEER . .

### 1—Gaseous Combustion at High Pressure

By William A. Bone, Dudley M. Newitt and D. T. A. Townsend (London)

400 pages 6½ x 10 Price $15.00

In the first chapters are described the new high pressure gas reseach laboratories at the Imperial College of Science and Technology and their equipment, as well as the apparatus and procedure employed. The experimental studies presented in this book consist chiefly of hydrogen-air, carbonic oxide-air and methane-air explosions at various initial pressures between three atmospheres and two hundred atmospheres. The authors have compared their results with those that have been conducted by other experimenters and this feature makes the book a valuable adjunct to the library of chemists and engineers who are interested in this line of work. The appendix contains a complete bibliography, a summary of the principal data relating to compressibilities of gases and a description of the new Bone-Newitt gas analysis apparatus now employed at the laboratory in which the experiments were conducted. The book is well illustrated and contains many charts, diagrams and tables. It is bound in cloth.

### 2—Hydraulics (4th Edition, Revised 1932)

By E. H. Lewitt, B. Sc. (London)

384 pages 8½ x 5½ Price $3.00

Deals from first principles with the theory of hydraulics and its application. This is primarily a student's textbook and no attempt has been made to deal with design problems, which are beyond the scope of the engineering degree. Numerous worked-out examples from past B. Sc. examinations of the University of London are included; also a number of exercises, with answers, at the end of each chapter. A large amount of new matter has been added to the former edition of this book, giving the results of recent researches on the viscous flow of fluids. Contains numerous illustrations and diagrams; a summary of formulas, useful tables and data. Useful in the examinations for the A. M. Inst. C. E. and the A. M. I. Mech. E.

### 3—Steel Construction

450 pages 8¼ x 5¼ Price $2.00

The 1932 Handbook of the American Institute of Steel Construction, combines the information contained in their previous publications. Considerable new material has been added, and the data regarding the new sections recently produced by the rolling mills is complete up to the minute of publication. The arrangement is excellent. The fact that there is complete information on one page for each size section saves not only time but the possibility of error. Very attractively bound and indispensable in the office of anyone in the steel business.

### 4—Draft and Capacity of Chimneys

By J. G. Mingle

339 pages Illustrated Price $3.50

The most authoritative book ever published on the subject of draft and chimneys. The subject matter has been developed primarily from a theoretical standpoint and then amplified by experimental data gleaned from actual practice.

The author observes that draft, even to the expert, frequently contains an element of mystery, and that there is often a great deal of confusion and misconception on the subject. A careful study of this book will give a thorough and practical knowledge of this important subject. The book is profusely illustrated with graphs and charts. Many valuable tables are included and the index has been prepared for ready reference.

### 5—A Handbook of English in Engineering Use

By A. C. Howell

308 Pages Price $2.50

Here is a real up-to-the-minute handbook that should be on the desk of every technical writer. Most engineers have occasion to do considerable writing and will find this useful. Chapters are devoted to word usage and idioms, sentence and paragraph structure, composition, punctuation and the mechanics of writing and grammar. Examples cover letters, reports and technical articles.

### 6—Steam Tables and Mollier Diagram

By Joseph H. Keenan

Price $2.00

These new Steam Tables, extending to a pressure of 3,500 lb. per sq. in. and a temperature of 1000 deg. fahr., were developed from the latest experimental data secured by investigators in laboratories of Europe and those of the United States. The Symbols used in this work are taken from the latest test prepared by the A. S. A. Sub-Committee for Heat and Thermodynamics. A large copy of the new Mollier Diagram (23″ x 34″) is also included.

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**ADDRESS** _____

# Boiler, Stoker and Pulverized Fuel Equipment Sales

***As reported by equipment manufacturers to the Department of Commerce, Bureau of the Census.***

## Boiler Sales

Orders for 201 boilers were placed in February by 72 manufacturers

| | Number | Square feet |
|---|---|---|
| February, 1932 | 201 | 240,549 |
| February, 1931 | 461 | 487,456 |
| January to February (inclusive, 1932) | 472 | 472,530 |
| Equivalent period, 1931 | 1,012 | 1,011,080 |
| Total, 1931 | 7,508 | 6,327,262 |

NEW ORDERS, BY KIND, PLACED IN FEBRUARY, 1931-1932

| Kind | February, 1931 Number | February, 1931 Square feet | February, 1932 Number | February, 1932 Square feet |
|---|---|---|---|---|
| Stationary: | | | | |
| Water tube | 56 | 281,202 | 25 | 147,416 |
| Horizontal return tubular | 36 | 40,311 | 12 | 14,392 |
| Vertical fire tube | 60 | 17,163 | 33 | 7,238 |
| Locomotive, not railway | 2 | 886 | 9 | 10,031 |
| Steel heating | 276 | 127,367 | 109 | 49,277 |
| Oil country | 8 | 7,200 | 1 | 752 |
| Self contained portable | 20 | 11,829 | 11 | 6,443 |
| Miscellaneous | 3 | 1,498 | 1 | 5,000 |
| Total | 461 | 487,456 | 201 | 240,549 |

## Mechanical Stoker Sales

Orders for 62 stokers totaling 8,134 hp. were placed in February by 55 manufacturers

| | Installed under: Fire-tube boilers No. | Fire-tube boilers Horsepower | Water-tube boilers No. | Water-tube boilers Horsepower |
|---|---|---|---|---|
| February, 1932* | 62 | 8,134 | 24 | 8,418 |
| February, 1931 | 88 | 10,762 | 38 | 10,173 |
| January to February (inclusive, 1932) | 132 | 18,440 | 67 | 32,254 |
| Equivalent period, 1931 | 200 | 25,948 | 90 | 30,306 |
| Total, 1931 | 1,889 | 252,571 | 574 | 187,507 |

* Preliminary.

## Pulverized Fuel Equipment Sales

Orders for 12 pulverizers totalling 74,188 lb. were placed in February

**STORAGE SYSTEM**

| | Pulverizers: Total Number | No. for new boilers, furnaces and kilns | No. for existing boilers | Total capacity lb. coal per hour for contract | Water-tube Boilers: Number | Total sq. ft. steam generating surface | Total lb. steam per hour equivalent |
|---|---|---|---|---|---|---|---|
| February, 1932 | .. | .. | .. | ..... | .. | ..... | ..... |
| February, 1931 | 1 | .. | 1 | 40,000 | 1 | 29,100 | 375,000 |
| January to February (inclusive, 1932) | .. | .. | .. | ..... | .. | ..... | ..... |
| Equivalent period, 1931 | 3 | 2 | 1 | 100,000 | 2 | 80,277 | 1,079,000 |
| Total, 1931 | 8 | 7 | 1 | 250,000 | 4 | 126,471 | 1,797,000 |

**DIRECT FIRED OR UNIT SYSTEM**

| | Pulverizers: Total Number | No. for new boilers, furnaces and kilns | No. for existing boilers | Total capacity lb. coal per hour for contract | Water-tube Boilers: Number | Total sq. ft. steam generating surface | Total lb. steam per hour equivalent |
|---|---|---|---|---|---|---|---|
| February, 1932 | 12 | 10 | 2 | 74,188 | 10 | 75,911 | 742,200 |
| February, 1931 | 2 | 2 | .. | 8,000 | 1 | 7,570 | 75,000 |
| January to February (inclusive, 1932) | 19 | 15 | 4 | 103,788 | 16 | 106,709 | 1,010,950 |
| Equivalent period, 1931 | 10 | 6 | 4 | 48,500 | 10 | 50,540 | 487,675 |
| Total, 1931 | 72 | 52 | 20 | 450,960 | 58 | 417,327 | 4,455,595 |
| | | | | | Fire-tube Boilers | | |
| February, 1932 | .. | .. | .. | ..... | .. | ..... | ..... |
| February, 1931 | 3 | .. | 3 | 2,250 | 3 | 3,000 | 22,350 |
| January to February (inclusive, 1932) | .. | .. | .. | ..... | .. | ..... | ..... |
| Equivalent period, 1931 | 9 | .. | 9 | 8,250 | 9 | 10,500 | 75,700 |
| Total, 1931 | 35 | 11 | 24 | 39,300 | 37 | 59,761 | 347,100 |

*Even a Bessemer Converter is not too hot for*

# CE-CO

## HI-DEGREE GRAY COATING

***The only paint that will withstand temperatures up to 1400 deg. fahr. and higher.***

**CE-CO Hi-Degree Gray Coating produces a pleasing dark gray finish which will not crack or peel on bare metal surfaces subjected to temperatures ranging from 600 to 1400 deg. fahr., or even higher. This coating also resists corrosion from weather exposure and ordinary plant and stack fumes.**

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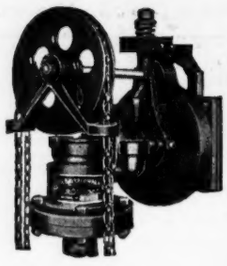

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